# ASTRONOMY®

## HOW TO MAKE A TIME MACHINE

## New Pulsar Planets Found

## Discover the Summer Sky

June 1992 **U.S. $2.95**
U.K. £1.75
Can. $3.50

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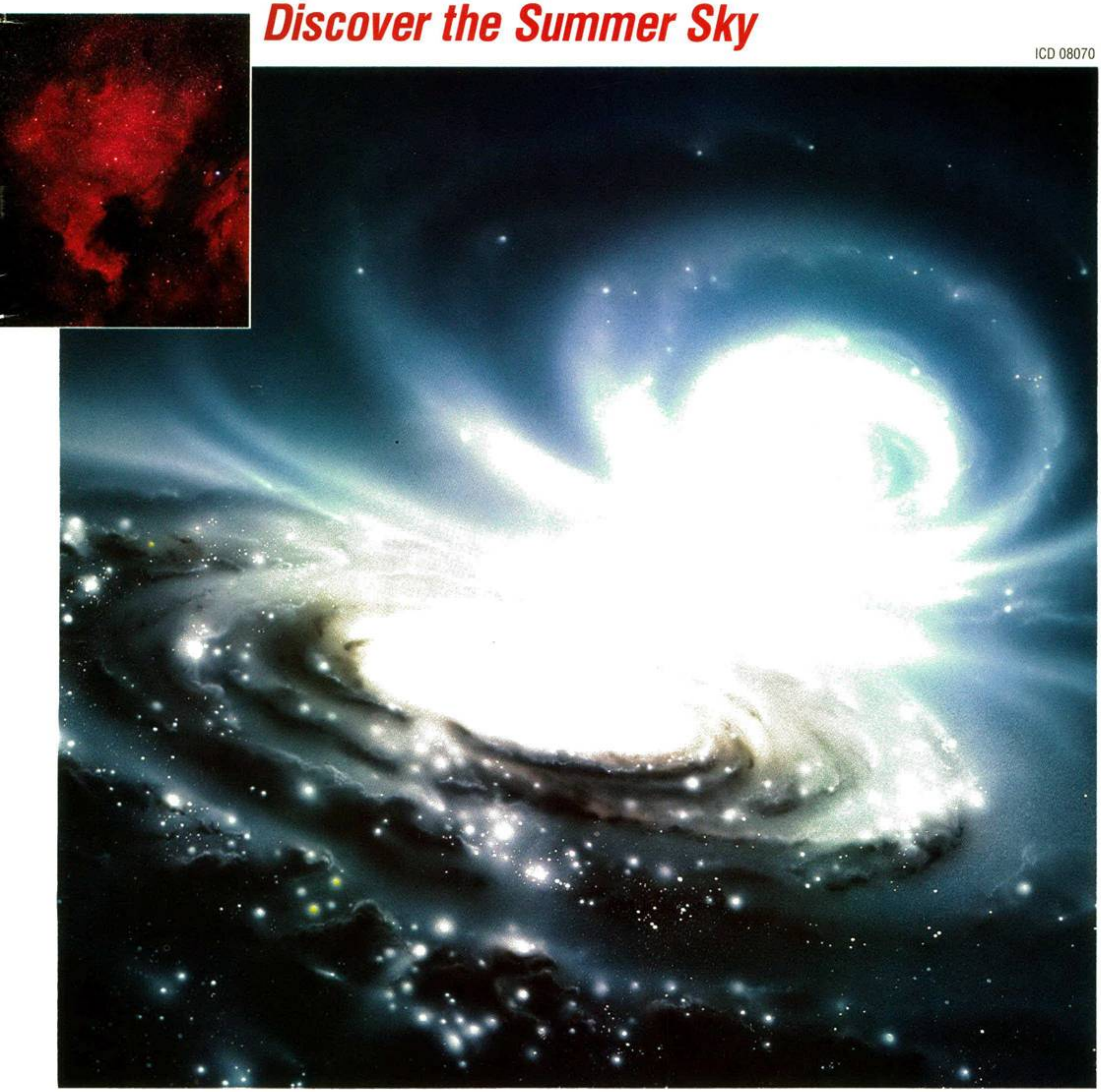

## Cosmic Wormholes: Tunnels through Time

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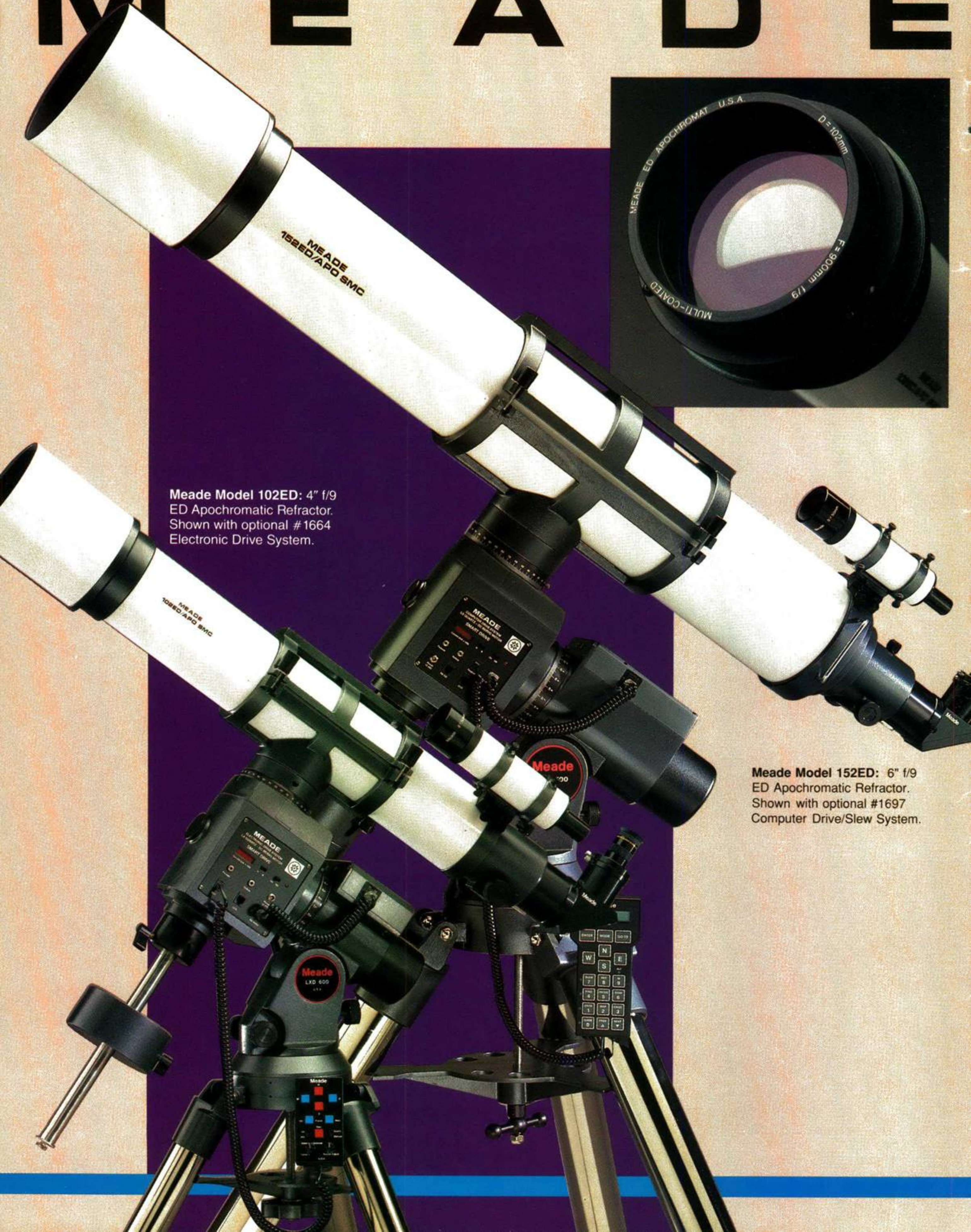
# MEADE®


MEADE 152ED/APO SMC
MEADE ED APOCHROMAT U.S.A. D=102mm F=900mm f/9 MULTI-COATED
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ENTER MODE GO TO
N W E S

**Meade Model 102ED:** 4″ f/9 ED Apochromatic Refractor. Shown with optional #1664 Electronic Drive System.

**Meade Model 152ED:** 6″ f/9 ED Apochromatic Refractor. Shown with optional #1697 Computer Drive/Slew System.

# *ED* APOCHROMATIC REFRACTORS

## The finest optical imaging performance obtainable, combined with the most advanced equatorial mounts ever made available.

### Have you ever wished you could observe with an instrument that yields the finest, textbook-perfect star images obtainable from any telescope? *Now you can.*

**Meade USA-made ED Apochromats** combine absolutely uncompromised image quality with a level of equatorial mounting precision, stability, and sophistication heretofore only dreamed of by the advanced amateur. *If you're looking for the most nearly perfect, ultra high resolution, high-contrast images of the skies that astronomical instrumentation—of any type—can provide, then a Meade apochromatic refractor is for you.*

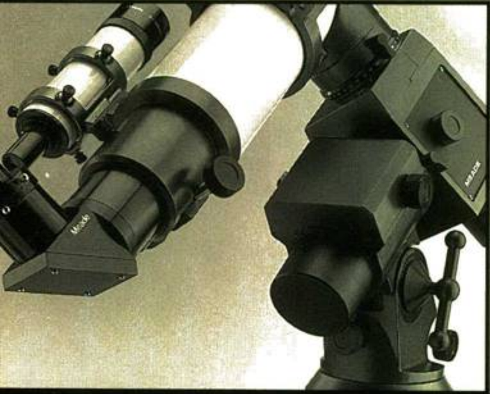
**Optical Designs**—Each 4", 5", 6", and 7" Meade apochromat includes an f/9 objective lens doublet with ED-glass (Extra-low Dispersion) rear element. Corrections for chromatic and spherical aberrations, for coma and astigmatism, and for lateral distortion are as faithful to optimized design criteria as can be obtained in any telescope. The front element of each objective is 2-side **Super Multi-Coated (SMC)** for maximum light transmission and image contrast.

**Optical Tube Assemblies** include the new Meade #684 giant rack-and-pinion focuser, with eyepiece-holders for both 1.25" and 2". The large 2.7" I.D. focuser sleeve permits the use of either 35mm or large-format professional camera bodies.

**High-Contrast Baffling**—Every Meade apochromat main tube includes a series of ***ten or more*** internal field stops and light baffles that effectively eliminate any stray light reaching the focal plane. Images of breathtaking sharpness, resolution, and contrast leap out against an extremely dark-sky backdrop.

**Equatorial Mountings**—As important to the serious observer as superb imaging performance, all-new state-of-the-art Meade LXD 600 and LXD 700 equatorial mountings will revolutionize forever the way amateur astronomers think about telescope mounting platforms. Consider:

- Massive polar and declination castings with oversize thrust surfaces.
- Worm-gear tracking and microfine manual slow-motion controls in both RA and Dec.
- *Eight* sealed ball bearings *(4 on each axis!)* carry even heavy loads with supreme precision.
- Superstable field tripods, including a new Meade Giant Field Tripod with 6" and 7" APO models.



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LX QUARTZ - DC SERVO MOTOR
SMART DRIVE
Current (mA x 100)
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S
On
Off
Focuser
Reticle
Power 12 vDC
RS 232
Keypad
LX Motor
CCD
Encoders

**Optional Electronic Drive Systems**—Two new dual-axis, DC-servo-motor-controlled electronic drive systems are available for the LXD 600 and LXD 700 mounts; both drive systems fully integrate internally to either mount:.

■ ***#1697 Computer Drive/Slew System:***

**Four dual-axis drive speeds** for (a) photoguiding corrections (at **2x** sidereal rate); (b) image centering and microslewing in the main telescope (at **32x** sidereal rate); (c) image centering in the viewfinder (at **2° per second**); and fast-slewing of the telescope across the skies (at **8° per second**). Use the keypad controller to switch speeds instantly as you move the telescope electronically with a pointing accuracy never before available.

**Permanently programmable (PPEC) Smart Drive**™ capable of reducing RA periodic drive errors to 5 arc secs. or less.

**Digital Readouts** on both telescope axes, read from the handheld Electronic Command Center.

**GO TO Capability:** Enter the RA and Dec of an object, punch GO TO, and the telescope automatically slews on both axes at 8° per second to the object, centering it in the field.

**747-Object Built-in Library:** Enter any of the 110 Messier objects, 278 of the finest NGC objects, 351 stars (doubles, variables, polar alignment stars), or one of the 8 major planets from Mercury to Pluto; punch GO TO, and the telescope automatically slews to the object. For $99* add the optional Meade 8000-object CNGC library to the software (a 30-second plug-in).

**Keypad operation** of virtually every telescope function, from tracking rates to the crossline brightness of an illuminated reticle eyepiece.

**Polar alignment** of the Mount: Quick (less than one minute) and precise, using the 2-star method.

■ ***#1664 Electronic Drive System***—For users not requiring the microprocessor-controlled capabilities of the #1697 Computer Drive, the #1664 system includes 2 dual-axis drive speeds (**2x** and **32x**); permanently programmable (PPEC) Smart Drive; object tracking-rate control, including quartz-controlled sidereal rate; and other features.

### Complete ED Apochromatic Refractors

**Specifications**—Each complete telescope includes: optical tube assembly with #684 giant 2.7" focuser, 8 x 50mm viewfinder, #930 2" diagonal mirror with 1.25" adapter, and Super Plössl 26mm eyepiece; 4" and 5" models include the LXD 600 equatorial mount and standard field tripod; 6" and 7" models include the LXD 700 equatorial mount and giant field tripod; each mount is provided with manual slow-motion controls, analog setting circles, and locks on both axes.

### Special Introductory Pricing Through 5/31/92*:

| | | |
|---|---|---|
| **Model 102ED:** | 4" f/9 ED/APO complete | **$1795.** |
| **Model 127ED:** | 5" f/9 ED/APO complete | **2295.** |
| **Model 152ED:** | 6" f/9 ED/APO complete | **3995.** |
| **Model 178ED:** | 7" f/9 ED/APO complete | **4995.** |

### Drive Systems

| | | |
|---|---|---|
| **#1664** | Electronic Drive System | **$295.** |
| **#1697** | Computer Drive/Slew System | **595.** |

### Optical Tube Assemblies (OTA's)

Each OTA includes complete tube assembly with #684 giant 2.7" focuser. Supplied without viewfinder or accessories.

| | | |
|---|---|---|
| **Model 102ED/APO-OTA:** | 4" f/9 | **$1075.** |
| **Model 127ED/APO-OTA:** | 5" f/9 | **1595.** |
| **Model 152ED/APO-OTA:** | 6" f/9 | **2295.** |
| **Model 178ED/APO-OTA:** | 7" f/9 | **2995.** |

### Equatorial Mountings

| | |
|---|---|
| **LXD 600 Mount & Standard Field Tripod** | **895.** |
| **LXD 700 Mount & Giant Field Tripod** | **1995.** |

■ *Prices shown are suggested USA mail-order retail prices and do not include sales taxes or shipping, if applicable.

■ The 1992 Meade General Catalog—$3.00 postpaid—is available from any authorized Meade dealer or directly from Meade Instruments.

■ **For further information on Meade ED Apochromatic or Schmidt-Cassegrain telescopes, or on any Meade product, call Meade Instruments toll-free at 1-800-854-7485 (in Calif. 714-556-2291), or contact one of these authorized mail-order dealers:**

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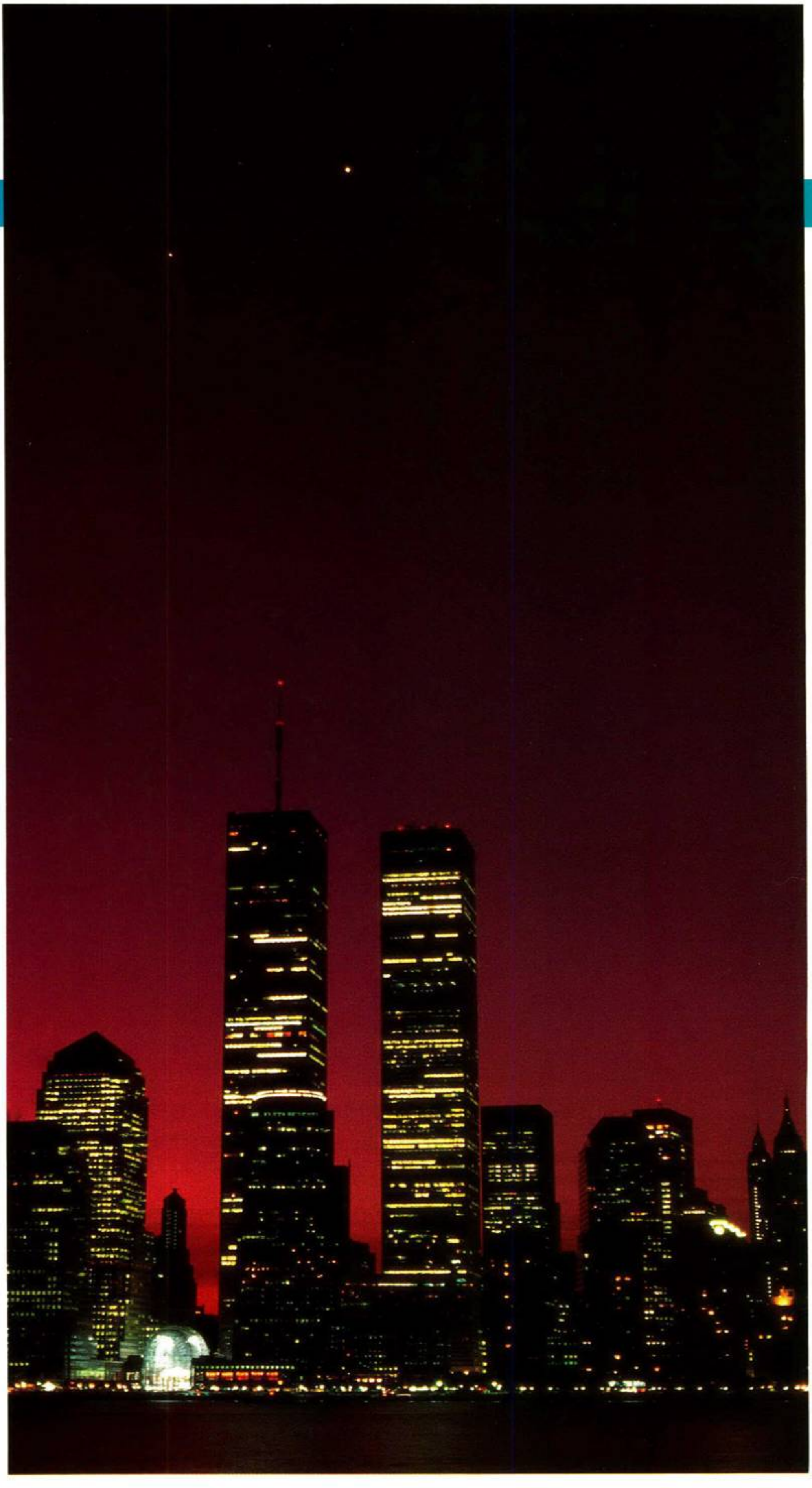
**ON THE COVER:** Relativity theory predicts that tunnels through the fabric of space called wormholes may one day enable astronauts to travel into the past or future. To learn how, see "Tunnels through Time" beginning on page 28. Art by Mark Paternostro.



**THE CITY AND THE SKY** combine for a beautiful "nightscape" in Larry Landolfi's portrait of the New York skyline and the meeting of Venus, Jupiter, and the star Regulus last October. For details on capturing your own nightscapes, turn to page 72.

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The Audit Bureau

## Behind the Scenes

# COSMIC WORMHOLES, PULSAR PLANETS, AND TELESCOPE FAIRS

Is time travel possible? Speaking practically, it's not. But as astronomer Barry Parker points out in "Tunnels Through Time" beginning on page 28, general relativity allows some pretty far-out possibilities. Researchers have found that relativity can provide explanations for astrophysical phenomena that Einstein never dreamed of. It seems rash to rule out anything this extraordinarily versatile theory allows.

Until recently, the idea of planets' circling pulsars was equally exotic. But in last December's issue we reported on the first discovery of a planet orbiting a pulsar in Scutum. And no sooner was that discovery made public than a different team of astronomers announced a *second* pulsar planetary system — with at least two planets in it! Then, in a dramatic announcement at the January 1992 meeting of the American Astronomical Society, the discoverers of the original system retracted their finding. Uncorrected errors in their data had led to an erroneous conclusion. Associate editors Dave Bruning and Dave Eicher were there when the announcement was made; don't miss Dave Bruning's report (page 36).

Radio astronomy has contributed so much to astronomy that it's hard to imagine how much poorer our view of the cosmos would be if it didn't exist. Somewhat surprisingly, this vital part of modern astrophysics was developed largely by an electrical engineer and amateur astronomer named Grote Reber. Robert Wearner tells the absorbing story of how Reber created this fledgling science virtually by himself during the 1930s and '40s (page 46).

If you're new to backyard astronomy — or just want to brush up your star-finding skills for summer — I invite you to turn to page 66. There, Eye on the Sky columnist Deborah Byrd debuts a new series on learning the constellations and their lore. You won't find a more graceful introduction to the nighttime sky. And if you have even a simple camera, don't miss the story by Robert Bunge on page 72. He'll show you how to capture breathtaking celestial scenes, the only real limit being your own imagination.

One final note. I hope to meet many of you this month at Universe 92. Held in Madison, Wisconsin, from June 20 to 25, this is a conference and telescope fair put on jointly by the Astronomical Society of the Pacific and ASTRONOMY. It's your chance to see and handle all the latest equipment, talk to manufacturers and dealers, and hear great talks on astronomy from experts, both amateur and professional. Three of ASTRONOMY's staff — Alan Dyer, Dave Eicher, and Tom Hunt — are speaking on such subjects as selecting the right telescope, the joys of deep-sky observing, and the glories of space art. For full details, call the Astronomical Society of the Pacific (415) 337-1100. Hope I'll see *you* there!

Sincerely,

Robert Burnham
Editor

ASTRONOMY

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## Letters

### General Assembly of the RASC

Commencing July 1, 1992, the Calgary Centre of the Royal Astronomical Society of Canada (RASC) will host the RASC's general assembly. This national convention is expected to attract some 150 amateur and professional astronomers from Canada and the U.S. as well as a large percentage of the 200+ local Centre members.

The gathering will blend formal and informal events, the keynote address being the Helen Hogg lecture. Our guest speaker this year will be Dr. Alan Hildebrand, who discovered the Yucatan Meteorite Crater.

We welcome any ASTRONOMY readers who wish to come to this event. For further information write the undersigned. — *Ruth Lewis, President, Royal Astronomical Society of Canada, Calgary Centre, P.O. Box 2100, Station M, Calgary, Alberta, Canada T2P 2M5*

### Slimmest Lunar Eclipse

Eye on the Sky and Through the Eyepiece in the December issue state that the December 21, 1991 lunar eclipse was the slimmest eclipse (9 percent of the Moon's disk covered) in over thirty years. However, the February 21, 1970 partial lunar eclipse had only 5 percent of the Moon immersed in the Earth's umbra. — *Vince Dangolovich, Harrisburg, Pennsylvania*

### More Naked-Eye Observing

I thoroughly enjoyed Alister Ling's article on naked-eye observing of deep-sky objects (January 1992). It was so good it left me wanting more!

Although Mr. Ling mentioned 25 objects that can be seen from mid-latitudes in the Northern Hemisphere, I wish the article would have mentioned more objects. How can you look at star clusters M36, M37, and M38 without observing the asterism made of 16, 17, 18, and 19 Aurigae? The "coat-hanger" and many other Collinder open clusters were overlooked. Even in northern locations, NGC 6231 in Scorpius stands out. I have never identified M16 and M17 without optical aid, but I have seen Melotte 186, NGC 6633, IC 4665, and M39.

I strongly suggest another article on naked-eye sights. Amateur astronomers have compiled Messier and Herschel lists, so why not a naked-eye list? — *Jack Megas, Springfield, Massachusetts*

### Mirror-Cleaning Tips

I found Michael Porcellino's article "How to Clean Your Mirror" (March

# Genesis Owner Turned Into Zombie!

Gentlemen:

I would like to say a few words about my new Genesis. I live in a relatively light polluted area, and own an 8" SCT which I have used for about two years. During this time there have been many deep sky objects which I have been unable to locate from my back yard.

I bought Genesis because I wanted a telescope that I could set up quickly to use at home on week-nights. When I began using Genesis, a few weeks ago, I was surprised to find many objects that have eluded me during the past two years. I was even more surprised when I realized that I had been looking in the right places all the time. These objects showed up in Genesis, but not in my 8" SCT.

My back yard experience with Genesis encouraged me to take it to my dark sky observing site which is, at an elevation of 5000 feet above sea level, in the Sierra Nevada Mountains. What I saw there was, in many cases, better than photographs in magazines. I was able to resolve globular clusters to a greater degree than publications indicate.

I didn't expect Genesis to be this good. It really is better than I imagined.

There does seem to be one problem with Genesis. My short week-night observing sessions have become anything but short, and I frequently arrive at work feeling and looking very much like a zombie. I guess that no telescope can solve all of your problems. In any case, thanks for the ones you did solve.

*- George N. Storm, California*

Photo by Jim Riffle

## Unsolicited comments from warranty cards

- *It's beautiful, from case to scope.* C.C. The Netherlands
- *Fantastic! Great photo resolution, best optics ever owned and I'm a Hasselblad & Nikon fan. Now my best item.* D.B. New Jersey
- *This is my 1st scope and I'm having a wonderful time finding the limits of the instrument and my locating abilities.* G.P. New Jersey
- *Very pleased with your new improvements.* J.F. California
- *Even though cost was more than an 8" SCT with mount, quality & convenience won out. I will only use Tele Vue optics, mount and accessories.* W.B. Indiana
- *The telescope lives up to its expectation.* T.W. England
- *Wanted a 2nd telescope that was portable, delivered wide fields and superb images. Genesis is all I hoped for. The sharpness is astonishing and it's very portable.* G.H. Canada
- *Sold my 8" SCT looking for better images.* P.F. New York
- *Fantastic! My wife could not see Trapezium etc. with old scope. Now can't get her away from eyepiece: you have right to be enthused about your product.* W.J. Canada
- *I just wanted to have one excellent telescope to do astrophotography. Fantastic. Awesome.* J.J. California
- *Beautiful equipment - Total satisfaction with first use. Keep up the good work.* M.C. Ohio
- *I wanted a very high quality refractor. I was told by many - "This is it." This is a beautiful instrument!* M.F. Florida
- *Remarkable! I always wanted a 4" fluorite refractor. Sold my (8" SCT).* T.S. Indiana
- *Compactness & quality - a beautiful, fantastic instrument.* J.V. The Netherlands

- *It's the best 4" refractor made.* A.A. California
- *I was looking for the best first telescope I could buy. Something small. I never saw images clearer and more distinct than in Genesis.* G.D. Canada
- *Genesis is the only scope in the race. I wanted the best and believe I got it.* E.S. Australia
- *As the apparent equal of a (Maksutov), with the added RFT capability, Genesis is 'the', to me, obvious choice for portable astronomy. I'm completely satisfied.* R.A. Georgia
- *Very Impressive - my first view was of Pleiades with a 40mm Wide Field. The observation was remarkable, crisp, bright and jewel-like.* P.L. Massachusetts
- *The best on the market.* E.B. England
- *I bought this telescope without having seen it in-person, based on its specification & your reputation for quality. As usual, I got more than I expected with Tele Vue products...* K.L. Texas
- *My friend borrowed it & won't give it back!!* T.L. Canada
- *I wanted portability and very high quality optics. I have waited many years to be able to afford this telescope, - it was worth waiting for.* P.H. Australia
- *Superior to other 4" scopes on offer.* Z.V.S. South Africa
- *Had SCT, poor contrast/resolution. Tele Vue just the opposite, also it's more portable.* W.S. Connecticut
- *I purchased this instrument because:*
  *1) Apo-refractor - basic design*
  *2) Tele Vue reputation*
  *3) Dealer owns same model*
  U.B. Canada
- *Genesis is as good as gold...Maybe better!* F.G. California
- *I compared specs of Tele Vue vs (other high performance refractors); T-V best choice for $.* R.A. New Hampshire
- *Magic.* C.H. England

My sincerest thanks to all who've written us with such kind comments. I look forward to reading yours.

Al Nagler

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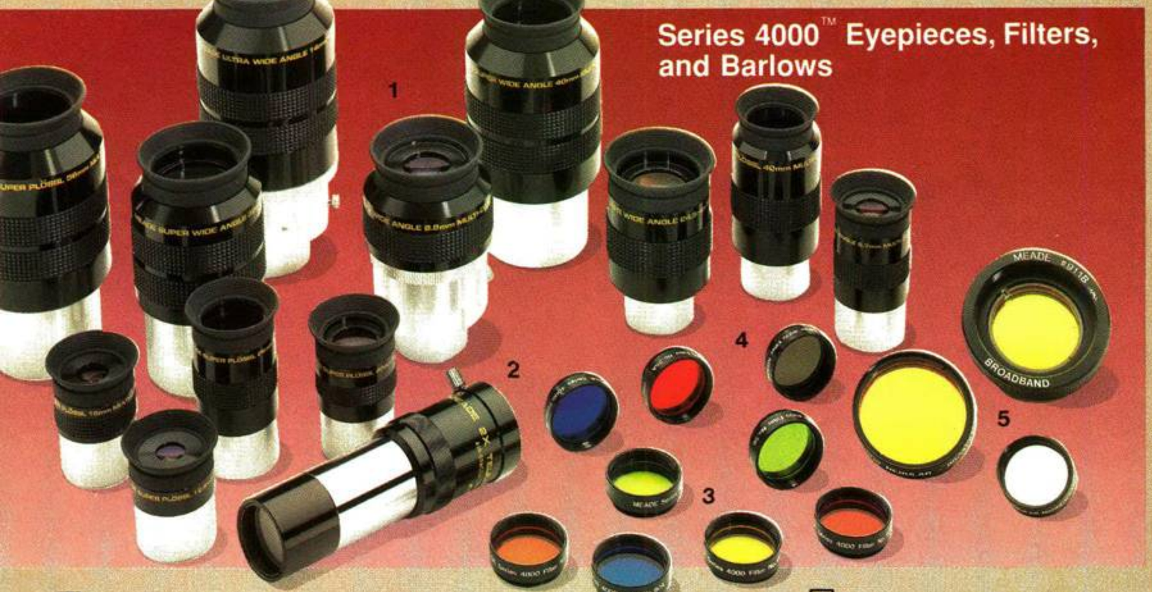
# GENUINE MEADE ACCESSORIES & PARTS



## Series 4000™ Eyepieces, Filters, and Barlows

**1** The World's finest telescope eyepieces now include rubber grips and soft rubber eyeguards for an even better observing experience! All eyeguards fold down for eyeglass wearers—a feature not available on competing brands. Best of all, **Meade Series 4000's are guaranteed to deliver more field, more contrast, and more image sharpness than any other brand at any price, or your money back.*** For splitting the closest doubles, revealing tenuous, faint nebulosity in deep-space, or studying hairline lunar and planetary detail, Meade multi-coated Series 4000's are the oculars that serious observers insist upon. ***"Clearly the best."***

**Super Plössls** (5-elements; 1.25"; 52°):
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**32mm**(52°); **40mm**(44°); each **99.95**(2.49)
**56mm** (52°, 2") **219.95**(3.18)

**Super Wide Angles** (6-elements; 1.25"; 67°):
**13.8mm:129.95**(2.49) **18mm:139.95**(2.49)
**24.5mm:159.95**(2.49) **32mm**(2")**:229.95**(3.18)
**40mm**(2"): **279.95** (3.18)

**Ultra Wide Angles** (8-elements, 1.25"; 84°):
**4.7mm: 147.95** (2.49) **6.7mm: 187.95** (2.49)
**8.8mm**(1.25"/2"): **219.95** (3.18)
**14mm**(1.25"/2"): **249.95** (3.18)

*at participating dealers; see catalog for details.

**2** **#140: Series 4000 2x Apochromatic Barlow Lens** (1.25")--The original Meade 3-element, air-spaced, multi-coated design. Absolutely unmatched in image resolution and color correction. 28mm dia. lens (26mm clear aperture). **$69.95** (2.49)

**3** **Series 4000 Photo-Visual Color Filters** (1.25")—Made of purest crown optical glass, dyed in the mass. For increased contrast on the Moon and planets. Thread into virtually all 1.25" eyepieces sold today. Fully coated.
**#8 Lt. Yellow; #11 Yellow-Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue.**
each **$12.95** (1.79)

**Set #1**—4 filters: #12 Yellow, #23A Lt.Red, #58 Green, #80A Blue **$42.95** (2.49)

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**5** **Series 4000 Nebular Filters**—The very latest in multi-layer interference coating technology, Meade premium nebular filters are guaranteed to be the finest obtainable at any price. Use a Series 4000 Broadband filter to block most forms of light pollution, with minimal attenuation of desired wavelengths. Use a Narrowband filter in heavily light-polluted areas, or for extremely high contrast observing of faint nebulae.

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**#908B** (1.25")—Threads into all Meade 1.25" eyepieces, and virtually all other brands. Full 26mm clear aperture. **$67.95**(1.79)

**#910B**—Threads into all Meade 2" eyepieces and most others; 44mm dia. **99.95** (2.49)

**#911B**--Threads on to the rear cell of Schmidt-Cassegrain telescopes. **87.95** (1.79)

**NARROWBAND FILTERS**

**#908N** (1.25")—Threads into virtually all 1.25" eyepieces; 26mm clear aperture. **89.95**(1.79)

**#910N**—Threads into all Meade 2" eyepieces and most others; 44mm dia. **119.95**(2.49)

**#911N**--Threads on to the rear cell of Schmidt-Cassegrain telescopes. **109.95**(2.49)

## World's Most Advanced Illuminated Reticle Eyepiece

**Series 4000 Plössl 9mm,** with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Internal batteries included. Multi-coated optics. Bullseye reticle. 1.25" **$119.95** (2.79)

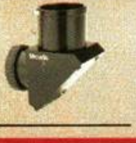
**Series 4000 Plössl 9mm**—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator. **$99.95** (2.79)

## MA 12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Includes wireless red LED illuminator with internal batteries and variable brightness control. **$89.95** (2.79)

**MA 12mm**-Same as above, but with cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$69.95** (2.79)

## 2" Diagonal Mirror



**#929:** Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter **$89.95** (2.79)

## Camera Adapters (1.25" & .965")

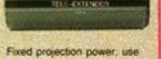
Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-Mount, available separately.

**.965": $24.95** (2.49) **1.25": $29.95** (2.49)

## Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-Mount for your camera. **$39.95** (2.49)

## Tele-Extenders



For Eyepiece-Projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Use with T-Mount for your camera.

**Basic Tele-Extender:***(above)* Fixed projection power, use with eyepiece for lunar and planetary photos. **$26.95** (2.49)

**Variable Tele-Extender:** Sliding cell, with lock, permits wide range of projection magnifications with the same eyepiece. **$36.95** (2.49)

## T-Adapters for SCT's

For Prime Focus photography with any Meade or Celestron SCT. Use with T-Mount for your 35mm camera. **$26.95** (2.49)

## 2X Telenegative Barlow (1.25")

**#122:** Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25" **$47.95** (2.49)

## 2x-3x Variable Barlow (1.25")

**#127:** Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25" **$59.95** (2.49)

## Orthoscopic Eyepieces (1.25")

Fine 4-element oculars that yield excellent image quality with any telescope. Computer-optimized design provides wide, flat fields, highly corrected for spherical and chromatic aberrations. Parfocal, multi-coated, 1.25" barrels. Threaded for filters. **Focal Lengths: OR 4, 6, 9, 12.5, 25mm.**

each **$47.95** (2.49)

## Modified Achromatic Eyepieces

An improvement on the traditional Kellner design, the 3-element MA gives sharp, faithful, well-corrected images of the Moon, planets, and deep-space. Multi-coated; threaded for filters. 1.25" **Focal Lengths: MA 9, 12, 25, 40mm.**

each **$37.95** (2.49)

## Rack-and-Pinion Focusers (1.25")

The finest focusers in the industry. Meade rack and pinion mechanisms have precise, ultra-smooth action along the entire travel distance. Housings are machined for tight fit of the moving sleeve. All focuser models may be used on tubes of from 4" to 20" diameter; all accept 1.25" eyepieces. Mounting hardware included.

**#71**—The finest economical focuser available. Travel distance: 2.2" A precision mechanism, beautifully finished. **$44.95** (2.49)

**#67**—Includes spring-loaded gearbox for variable tension adjustment. Travel distance: 2.2" **59.95** (2.49)

## Rack-and-Pinion Focusers (2")

**#680**--The most popular 2" focuser ever manufactured. Thousands in use. Spring-loaded gearbox; 3" travel. Includes 1.25" and 2" eyepiece-holders. **89.95**(3.48)

**#682**—Low-profile 2" focuser; body height only 1.75". Spring-loaded gearbox. Travel: 2.5". Includes 1.25" adapter. **99.95** (3.48)

## Viewfinders: 30mm, 50mm, 60mm

**#637: 6 x 30mm**-Fine, 7° wide-field finder; coated, achromatic lens; crosshair eyepiece, 2-ring bracket with alignment screws. Attaches to tube diameters 6" to 12" **$39.95** (2.79)

**#545: 8 x 50mm**-*(lower photo)* Wide 5° field; coated achromatic objective; crosshair eyepiece. White tube. Ideal for telescopes of any aperture. See bracket below. **59.95** (3.48)

**#544: 8 x 50mm**--
Same as #545, but in Meade blue. **59.95** (3.48)

**#957: 9 x 60mm**--*(top photo)* Collects 44% more light than 50mm; superior for faint objects; bracket below. **89.95** (3.78)

**Bracket for 8 x 50mm:** Fits Meade and Celestron SCT's, and other tubes from 7" to 20" diameter. **17.95** (1.79)

**Bracket for 9 x 60mm:** Fits tubes from 7" to 20" diameter. Removable dovetail included. **22.95** (1.79)

## Multi-Coated Giant Binoculars

Superb, fully multi-coated 11 x 80mm and 20 x 80mm Giant Binoculars, ideal for wide-field deep-space observing. **Rubber-coated bodies for rugged field use!** BAK-4 prisms yield bright, sharp, high-contrast images. Hard carry case, tripod adapter included.

**11x80: $359.95**(4.87)
**20x80: $379.95**(4.87)

## 45° Erect-Image Diagonal Prisms

Originally developed by Meade Instruments, these convenient diagonals erect the astronomical image, for terrestrial use of astronomical telescopes. Fully coated.

**#927:** for .965" focusers.
**#928:** for 1.25" focusers.
**#931 Hybrid:** accepts 1.25" eyepieces, fits .965" focusers.

Specify model desired. each: **$49.95** (2.49)

### HOW TO ORDER

- Prices shown are suggested USA mail-order retail prices and do not include any applicable sales taxes.
- Suggested shipping and handling charges to the 48 states by UPS or US Mail shown in ( ) next to each price.
- Meade accessories may be ordered from any Meade Advanced Products dealer. **The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:**

**ASTRONOMICS, Norman, OK.**
**Orders: 800-422-7876; Info.: 405-364-0858.**

**CALIFORNIA TELESCOPE CO., Burbank, CA**
**Orders: 800-843-4780; Info: 818-505-8424.**

**FOCUS CAMERA, Brooklyn, NY.**
**Orders: 800-221-0828. Info: 718-436-6262.**

**LUMICON, Livermore, CA.**
**Orders: 800-878-9577. Info: 510-447-9570.**

**SCOPE CITY/Mail-Order, Simi Valley, CA.**
**Orders: 800-235-3344; Info/CA:805-522-6701**

**SHUTAN CAMERA & VIDEO, Chicago, IL.**
**Orders: 800-621-2248; Info/IL: 312-332-2000.**

***Canada:***

**KHAN SCOPE CENTRE , Toronto, Ontario.**
**Orders & Information: 416-783-4140.**

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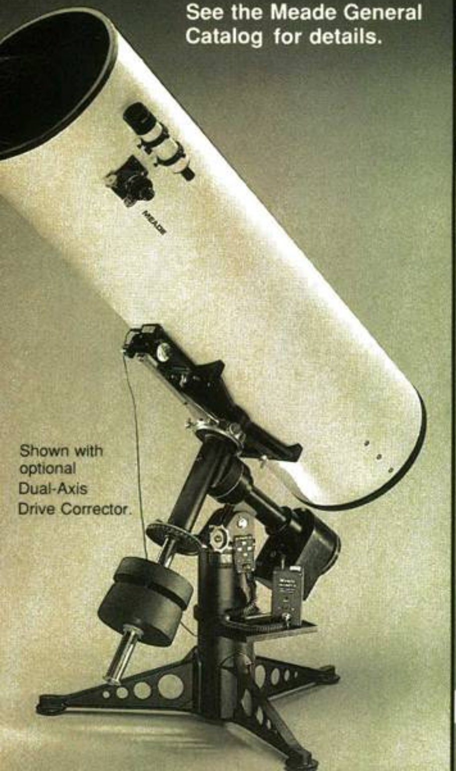
**10" f/4.5 $699.95**

**Starfinder 16: 16" f/4.5 $1995.**

**See the Meade General Catalog for details.**



Shown with optional Dual-Axis Drive Corrector.

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■ **Superb Optical System:** Includes a Meade hand-figured parabolic primary mirror that meets the theoretical limit of resolution for its aperture, with matching elliptical flat secondary mirror. Both mirrors multi-coated and made of fine-annealed Pyrex® glass.

■ **Precision Equatorial Mount:** Manufactured of virgin aluminum castings machined to tolerances of .001" or better, and placed atop a 4"-dia. pier with die-cast tripod legs, yielding rock-solid support for the optical tube assembly. The telescope moves effortlessly from object-to-object on precision bearing surfaces. Polar and declination shafts are 1" solid steel. Setting circles on both axes facilitate the location of faint sky objects directly from their catalogued coordinates.

■ **Electric Motor Drive** (115v./60Hz) with 6 ft. power cord: Permits fully automatic tracking of celestial objects; plugs into any standard outlet.

■ **Accessories and Components:** Meade Starfinder telescopes include high-performance components throughout: **#71 Rack-and-Pinion Focuser** (1.25") for smooth, backlash-free focusing of the image; a coated achromatic **#637 6 x 30mm Viewfinder** with crosshair eyepiece and 7° field, for quick object-locating; **coated MA 25mm** (1.25") eyepiece; strong, durable spiral-wound **optical tube** with attractive white finish; and **cast aluminum mirror cell** for accurate mounting and alignment of the primary mirror.

■ **Optional Accessories:** See the opposite page for some of the many optional accessories available. Additional systems, including the **#55 Manual Declination Control**, **#43 Drive Corrector** and **#47M Dual-Axis Drive Corrector,** are described the **Meade General Catalog.**

**A Meade Starfinder telescope** opens up the skies to an extremely wide range of serious visual observing, to lunar and planetary photography, and even to limited deep-space photography. And every telescope is backed by the World's largest manufacturer of serious telescopes.

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**■ Packing & UPS Shipping Charges to any address in the 48 states: 6"--$50; 8"--$60; 10"--$75.**

■ Prices shown are suggested USA mail-order retail prices, not including any applicable sales taxes.

**■ The 1992 Meade General Catalog— $3.00 postpaid— is available from any authorized Meade dealer or directly from Meade Instruments.**

**■ For further information call Meade Instruments toll-free at 1-800-854-7485 (in Calif. 714-556-2291) or contact one of these authorized mail-order dealers:**

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**Orders: 800-422-7876; Info.: 405-364-0858.**

**CALIFORNIA TELESCOPE COMPANY, Burbank, CA.**
**Orders: 800-843-4780; Info.: 818-505-8424.**

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**LUMICON, Livermore, CA.**
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ADVANCED PRODUCTS DIVISION **Meade Instruments Corporation**

# *LX200* SCHMIDT-CASSEGRAINS

## Legendary Meade SC optics and the largest, most rigid, most advanced fork mounts in commercial Schmidt-Cassegrain history.

**Now you can buy the most advanced 8" and 10" Schmidt-Cassegrains ever produced, at a price directly competitive with other SCT's offering only a fraction of the features!**

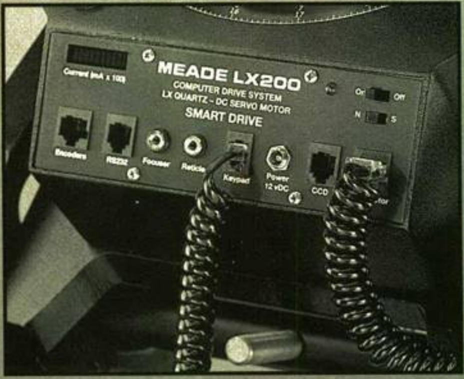
**Meade LX200 SCT's** offer a revolutionary departure from any other SCT's ever made available. Consider the **standard specifications** of these telescopes:

**New Heavy-Duty Fork Mounts**—The largest, most rigid in the industry. *Meade 8" and 10" LX200 fork mounts yield the lowest damping times of any SC fork mounts available.* Large 4"-diameter polar ball bearings complemented by DC-servo-motor-driven worm gears on ***both*** telescope axes permit observatory-level precision in tracking, guiding, and slewing.

**100% Computer-Controlled Operation**—All-new Meade LX200 microprocessor-controlled drive systems offer an incredible array of features:

■**Four-speed operation on both telescope axes** simultaneously, including (a) photo-guiding (at **2x** sidereal rate); (b) image centering and microslewing in the main telescope (at **32x** sidereal rate); (c) image centering in the viewfinder (at **2°** per sec.); or fast-slew of the main telescope across the skies (at **8°** per sec.).

■**Pushbutton Electric Slew**—Press RA or Dec slew, east or west, north or south, and the telescope moves at 8° per sec. on both axes. As you near a desired object, flip to 2° per sec. slew, to center the object in the field. The observer need never touch the telescope in moving from one object to another. (Of course, if you wish, the telescope may be moved manually as well.)



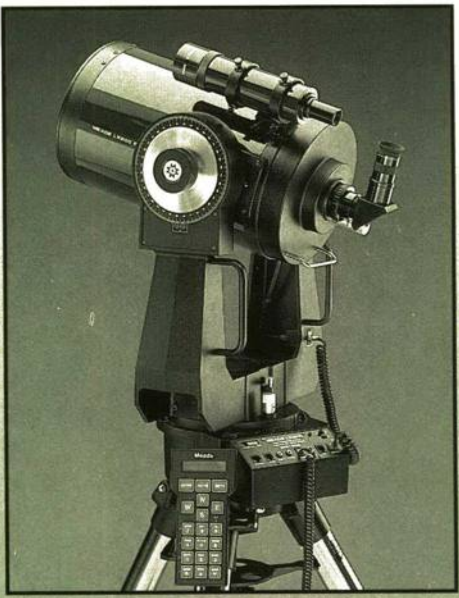
■**Digital Readouts** on both axes, read from the handheld Electronic Command Center (ECC).

■**GO TO Capability**—Enter the RA and Dec of an object into the keypad of the ECC, press GO TO, and the telescope automatically slews to the object at 8° per sec., centering it in the field.

■**747-Object Built-in Library**—Enter any of the 110 Messier objects, 278 of the finest NGC objects, 351 stars (doubles, variables, polar reference stars), or one of the 8 planets, from Mercury to Pluto, press GO TO, and the telescope slews at 8° per sec. to the object with uncanny precision. For $99* add the 8000-object Meade CNGC library, a 30-second plug-in.

■**Permanently programmable (PPEC) Smart Drive**™, capable of reducing periodic drive errors to 5 arc. sec. or less.

**Legendary Meade Super Multi-Coated f/6.3 or f/10 Schmidt-Cassegrain Optics**—Now you can choose either wide-field f/6.3 or classical f/10 Meade US-made SC optics **at the same price.** Either way, you'll be buying the finest Schmidt-Cassegrain optical system available, a system that yields razor-sharp stellar images and high-resolution observing of the Moon, planets, and deep-space, from the World's leading manufacturer. Meade exclusive Super Multi-Coatings on both sides of the correcting plate assure maximum light transmission and contrast.



**Altazimuth Mode Operation**—For all visual observing applications, and for lunar and planetary photography, Meade LX200's may be set up in the altazimuth mode, without any equatorial wedge—just attach the telescope's drive base directly to the tripod, use the fast 1-star alignment procedure, and the telescope's computer actuates 2-axis tracking that keeps objects precisely centered in the field, even at high powers, during the entire observing session. For long exposure photography (longer than about 5 minutes) altazimuth-induced field rotation requires an equatorial wedge, which may be purchased separately.

**Fast Polar Alignment**—Center two reference stars in the telescopic field and the telescope's computer tells you exactly what telescope controls to actuate for precise polar alignment in the equatorial mode in less than a minute.

**The widest array of keypad and power-panel control functions**—In addition to the microprocessor-controlled operations listed above, the handheld ECC and the telescope's power panel permit: readout of sidereal or local time; actuation of the optional electric focuser; crossline brightness control of an illuminated reticle eyepiece; direct plug-in of popular CCD autoguiders/imagers; and more than 14 other telescope functions.

### MEADE LX100 SCHMIDT-CASSEGRAINS

Observers not requiring the sophistication of the LX200 electronics may wish to consider an 8" or 10" LX100 model SCT instead. Meade LX100's include the exact same heavy-duty fork mounts of their LX200 counterparts, but with a microfine declination tangent arm control in place of the LX200's motorized worm gear, and with a 2-speed drive in place of the LX200's 4-speed drive; optical tubes and coatings are identical. Standard LX100 features include:

■ Handheld Electronic Command Center—With 2-speed operation, **2x** for photo-guiding and **32x** for image centering and microslewing in the main telescope. (With the optional DC-servo declination motor installed, these speeds are operational on both telescope axes.)

■ Permanently programmable (PPEC) Smart Drive, as described above.

### Complete LX100 and LX200 Telescopes

**Specifications: 8" and 10" LX200's**—Each complete telescope includes: 8" or 10" SC optical tube assembly (specify f/6.3 or f/10) with super multi-coatings; heavy-duty fork mount, with 4" polar ball bearing, dual-axis 5.75" worm-gears, and multi-function power panel display on the drive base; manual slow-motion controls on both axes; handheld keypad Electronic Command Center, with digital readout display, PPEC Smart Drive, four-speed drive control on both axes, GO TO controller, and 747-object software library; 25 ft. power cords for telescope operation from either 12 v. DC auto cigarette lighter plug or 115v.AC; 8 x 50mm viewfinder with crosshairs; diagonal prism (1.25"); Series 4000 Super Plössl 26mm eyepiece; variable-height field tripod; new deluxe die-cut-foam-fitted carrying case; complete operating instructions.

**Specifications: 8" and 10" LX100's**—Each complete telescope includes 8" or 10" SC optical tube assembly (specify f/6.3 or f/10) with super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, 5.75" RA worm gear, and multi-function power panel display on the drive base; manual slow-motion controls on both axes; handheld pushbutton Electronic Command Center with PPEC Smart Drive and 2-speed drive control; 25 ft. power cords for telescope operation from either 12v. DC auto cigarette lighter plug or from 115v. AC; viewfinder: 6 x 30mm (8") or 8 x 50mm (10"); diagonal prism (1.25"); Series 4000 Plössl 26mm eyepiece; variable-height field tripod; equatorial wedge (8") or Superwedge (10"); new deluxe die-cut-foam-fitted carrying case; complete operating instructions.

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### Special Introductory Pricing Through 5/31/92*:

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Supplied complete, per above specifications:

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|---|---|
| **8" LX200 Schmidt-Cassegrain** | **$1995.** |
| **Equatorial Wedge 8"** | **110.** |
| **10" LX200 Schmidt-Cassegrain** | **2295.** |
| **Superwedge 10"** | **395.** |
| **8" LX100 Schmidt-Cassegrain** with wedge | **1695.** |
| **10" LX100** with Superwedge | **2395.** |

■ *Prices shown are suggested USA mail-order retail prices and do not include sales taxes or shipping, if applicable.

■For dealer or catalog information see the Meade **ED Apochromatic Refractor** ad in this issue.

*ADVANCED PRODUCTS DIVISION*
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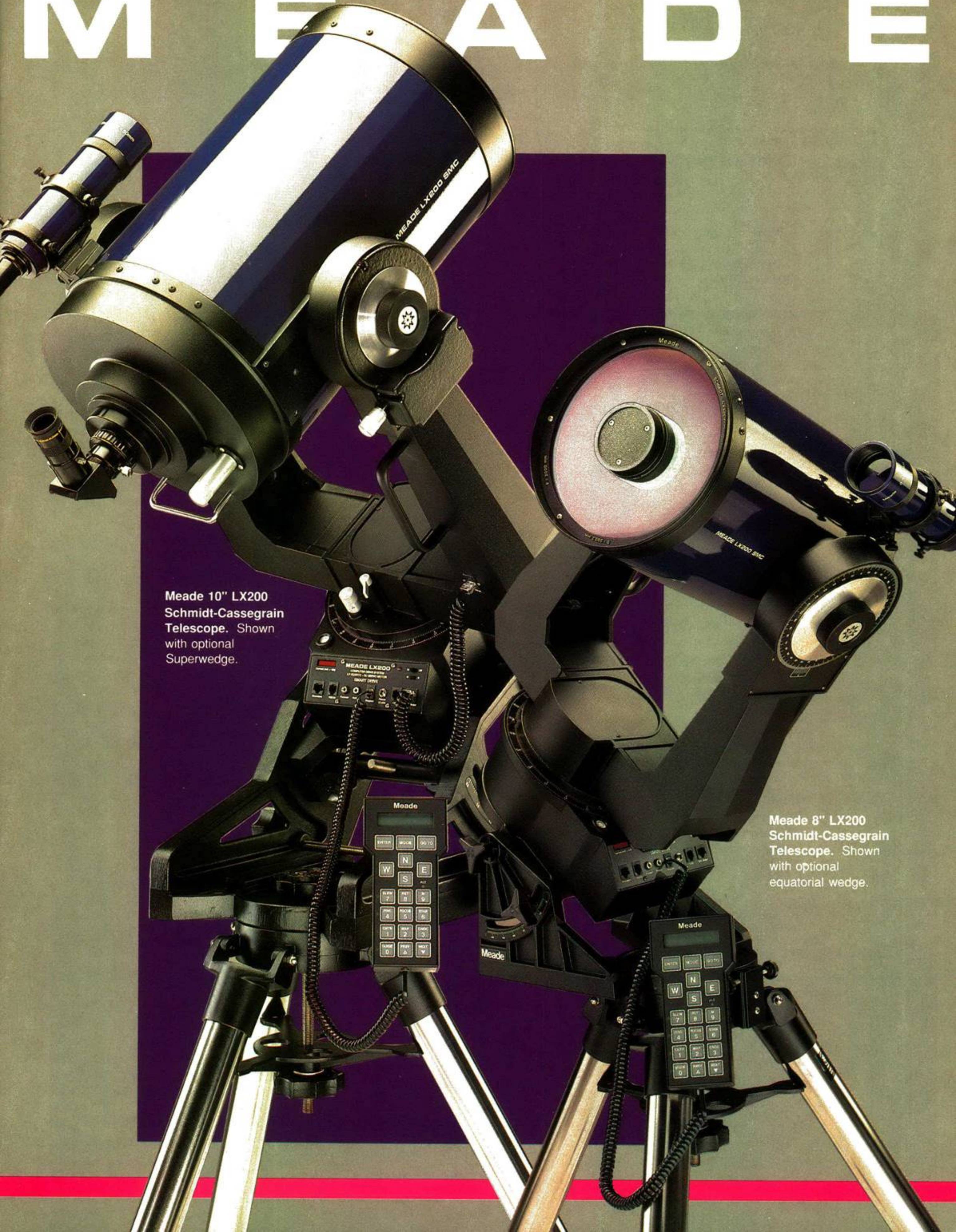
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**Meade 10" LX200 Schmidt-Cassegrain Telescope.** Shown with optional Superwedge.

**Meade 8" LX200 Schmidt-Cassegrain Telescope.** Shown with optional equatorial wedge.

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1992 issue) excellent reading. One aspect might be added, however: after the final rinse with water, I have had trouble with "water stains" (blotchy yellow marks). A friend suggested using isopropyl alcohol after the final rinse, and it works like a charm. — *Alan Pasicznyk, Doylestown, Pennsylvania*

### One Universe?

In looking over my back issues of ASTRONOMY, I came across a letter in the August 1990 issue by Alfred Reid objecting to such terms as island universe and other universes. He contended that the term universe encompasses everything that exists, has existed, or ever will exist. Therefore, there can only be one universe.

Astronomers used to believe that the solar system contained all there was to know, that it was the universe. Then they discovered the Galaxy and redefined the universe to include the new discovery. Then the universe was enlarged to include the discovery of other galaxies. Now these ideas are facing another era of revision and rethinking. Experience shows that ideas of the extent and content of the universe have always been limited. I suspect that some day astronomers will find that there are indeed "other" universes. — *Bill Broderick, Shannonville, Ontario, Canada*

### Now You See It . . .

One of my favorite cloudy night activities is browsing through the many volumes of photographs you've published over the years. It's especially interesting to compare different photos of the same area of sky.

I've noticed that two photos of the Sagittarius area published in the January 1992 issue are greatly different — one shows a tremendously bright star and the other doesn't. The photos are on page 80. What's going on here? — *Adrian Ross, Chisholm, Australia*

*— The "star" is not a star at all but Saturn, which moved through Sagittarius in 1987 and has since moved eastward into Capricornus.*

### Hot Tub Gets Hotter

As a retired navigator/bombardier for the Startegic Air Command, U. S. Air Force, I read with interest Beverly Mosier's article "Navigating the Celestial Hot Tub" (March 1992 issue). Ms. Mosier seems to have a grasp of the techniques and procedures used in celestial navigation and deserves high grades in class.

But she might want some remedial training in plotting geographic coordinates. The maximum north or south coordinate is 90° and Ms. Mosier plotted a point somewhere in the twilight zone at 117 degrees, 41 minutes North. On inspection, this appears to be a typographical error because her home plots in the vicinity of Laguna Beach, California, if you transpose the direction of the coordinates.

I wish Ms. Mosier good luck with her navigation course and suggest that she attempt to secure a good bubble sextant at an Air Force salvage sale. It will allow her to shoot the Sun, stars, and planets, day or night, without having to see the horizon. I still find it fascinating that something light-years away can be used to find my present position on Earth. — *Lieut. Col. Vincent B. Peck, USAF (Ret.), Jonesboro, Georgia*

### The Many Colors of Jupiter

I found two computer-processed images of Jupiter in your January 1992 issue, one on the cover and another in an advertisement. The cover shot depicts Jupiter with blue and yellow clouds, while the other image shows reddish brown clouds. Why are they so different, and which is correct? — *Jason Voegele, Cincinnati, Ohio*

*— The Jupiter images are both false-color products, meaning that colors have been added using an image processing computer program to enhance visible colors. Because final colors in a processed image can fall within a relatively wide spectrum and still look basically realistic, you're likely to see false-color images of the same objects showing slight differences in color for years to come.*

### Correction

The photographs in Gerrit L. Verschuur's article "Mysterious Sungrazers" (April issue) were erroneously credited to Dr. Verschuur. The source of the photos was the High Altitude Observatory in Boulder, Colorado. ☐

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*ASTRONOMY welcomes comments and additional information on articles and astronomy in general. Send your letters to ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187. Letters may be edited for length or clarity.*

# IS ASTROPHOTOGRAPHY DEAD?

by Richard Berry

In a word: No. Astrophotography may be challenged, and it may have entered a long rivalry with CCD imaging, but it is by no means dead.

Many of us are fascinated by CCD imaging and thrilled by the potential CCDs offer. But we also know what they cannot do.

On February 22 I attended a remarkable gathering of amateur astronomers. The meeting was the fourth Electronics-Oriented Astronomy Symposium, sponsored by the Orange County (California) Astronomers. It attracted well over a hundred technically oriented amateur astronomers to a long day of papers and talks about CCDs and the revolution that CCDs have created in amateur astronomy.

Listeners found the papers quite impressive. Alan Holmes from the Santa Barbara Instrument Group (SBIG), Steve Mac-Arthur of Spectra-Source, and Joe Maher of Photometrics spoke glowingly of the new cameras their companies are now offering or will shortly introduce. Before lunch, one of the gurus of scientific CCDs, Jim Janesick, of the Jet Propulsion Laboratory, described the complex technology that goes into making a good scientific CCD. By the time the conferees broke for lunch, the crowd had a case of pixel envy, and they had it bad.

Pixels are the raw stuff of images. They are the atoms of the imaging world, the indivisible elements of a picture. Think of a picture as tiny areas of brightness, areas small enough that each area has but a single brightness. A digital image is no more than a mass of numbers describing the brightnesses of pixels.

Large pixel counts give you the chance to make an image that covers a wide field of view or that records lots of detail over an extended region of space. Lots of pixels mean large sky coverage. From an imaging standpoint, a large pixel count is highly desirable.

Tim Hunter

With CCDs, chips with small numbers of pixels are cheap and plentiful. The Texas Instruments TC-211 chip, the heart of the SpectraSource Lynxx and SBIG ST-4 cameras, has 165 rows, each consisting of 192 pixels — so in all there are some 32 kilopixels on the chip. SBIG's new ST-6 camera, based on their implementation of the TC-241 chip, has a pixel count of 90-some kilopixels and a price that is correspondingly higher. SpectraSource has several cameras in the 300-kilopixel range coming down the pike and already offers the HPC-1, with a one-megapixel chip.

But a single frame of fine-grained film such as Tech Pan in its 35mm format offers five megapixels. Even the fastest, grainiest films you can buy today have pixel counts that exceed a megapixel per 35mm frame. When you need to cover a large field of view, or when you want to record a lot of detail over an extended area, photographic films beat the CCDs hands down.

Photographic film offers further advantages over the CCD film. Film is cheap, light, and portable; it requires no electricity and it's always ready to use. Color film produces beautiful images, in tints and shades and hues by the million. Today's films produce excellent astrophotographs with exposure times much shorter than we thought possible back in our high school days. Astrophotography is very much alive and will remain alive for years to come.

So what's the big fuss? Well, CCDs

(continued on page 16)

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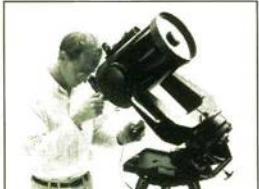

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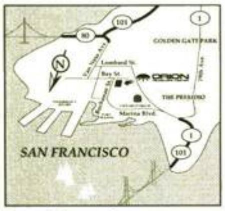

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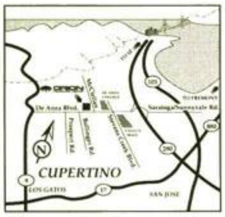

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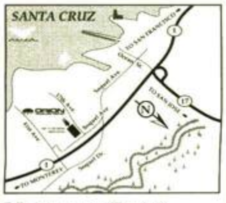

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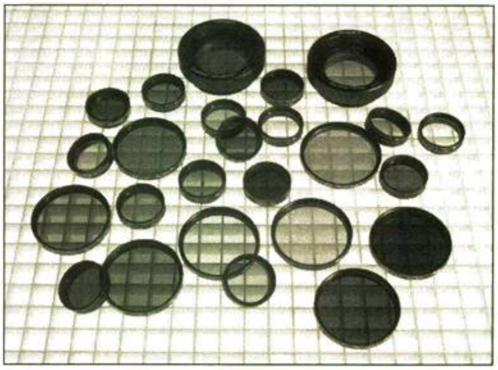

# Accessories

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have their advantages, too, and that every, once in a while, seems to bother some astrophotographers. When you wish to make images of small areas of the sky, CCDs gain the upper hand. CCDs are about ten times as efficient at recording light as the best films are, so you can use exposures with CCDs that are short compared to exposures with film. Furthermore, CCDs produce a linear output so that you can measure precisely how much light struck a given pixel. That means precise images that can be digitally enhanced.

These characteristics make CCDs — even very small CCDs — ideal for imaging the planets, for recording planetary nebulae, and for exploring individual galaxies anytime you're interested in a small piece of the sky. Thirty-two kilopixels is all that's required to nail down diffraction-limited views of Jupiter, Saturn, or Mars. Ninety kilopixels is more than enough to snatch any Virgo-cluster galaxy from the sky or to capture the intricate structure at the heart of the Orion Nebula.

But ask a CCD to cover three degrees of the Milky Way at the focus of a 6-inch refractor and you're talking a chip that's got 16-megapixels, a chip that has not yet been made. Or you could shoot one frame of 120-format ISO 400 film. Ask to image the Moon to the diffraction limit of a 16-inch telescope, and you're talking about 50-megapixels worth of image — an image that's just right for one 4" by 5" sheet of ISO 100. Astrophotographers: you have nothing to worry about!

CCDs even help us take astrophotos. At the symposium, two afternoon speakers showed slides they had taken using CCD-guided telescopes. Mike Stecker and Chris Schur both shot their pictures on film — hydrogen-hypered Tech Pan — and both used ST-4 CCD guiders to track their exposures. Mike sleeps or observes while his film exposes, while Chris keeps an ear cocked to the sounds his guider makes, listening to it through an intercom from inside his house. Both are pushing the limits of amateur astrophotography with longer exposures — an hour, two hours, three hours — and both have stunning results to show for it.

Finally, I offer this simple anecdote as proof that astrophotography is still alive. When the big aurora appeared last November, did I reach for a CCD camera? No. I grabbed my trusty 35mm camera and headed for the back yard. ☐

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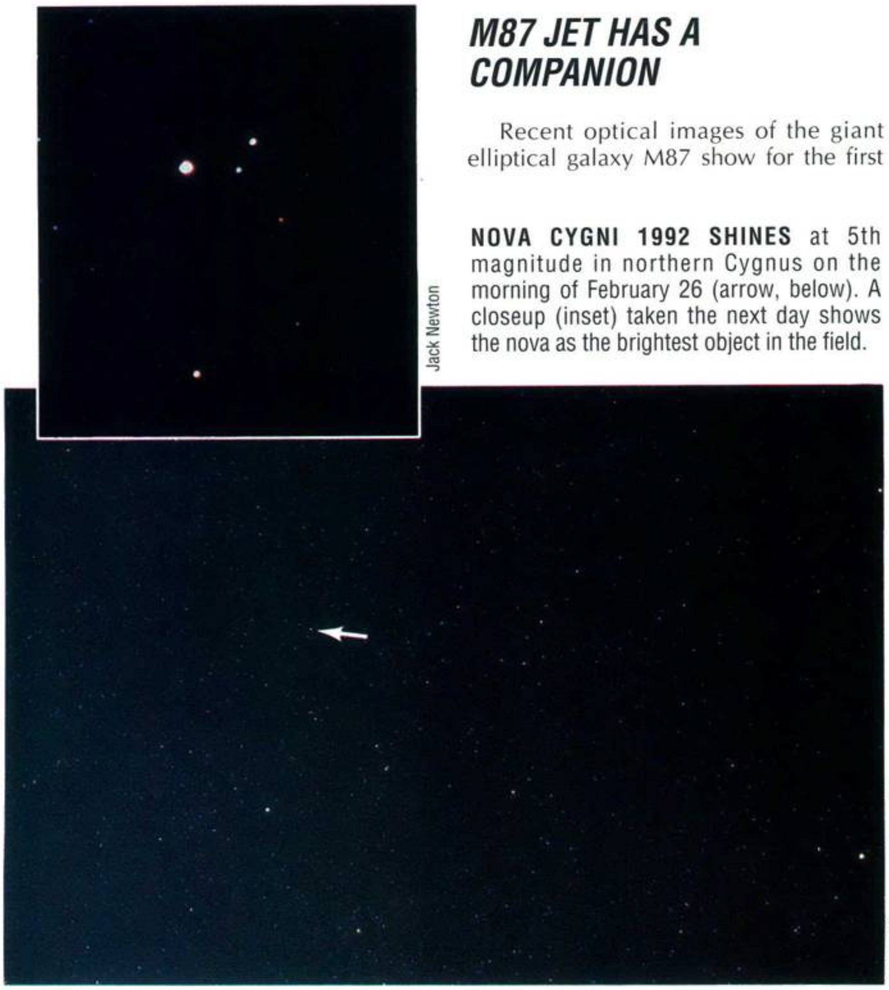
# BRIGHT NOVA IN CYGNUS

During the early evening hours of February 18, amateur astronomer Peter Collins of Boulder, Colorado, observed the constellation Cygnus as it set in the northwest. But Cygnus didn't appear quite the same as usual. An unexpected new star — or nova — shone within the constellation's boundaries. Its precise position (equinox 2000.0) is right ascension 20h30m32s and declination 52°37'53", about 3.5° due north of Omega$^2$ Cygni.

At the time of his discovery, Collins estimated the brightness of the nova at magnitude 6.8. As Cygnus rose the next morning, the nova had brightened to magnitude 6.0. (Cygnus lies far enough north that during February it is visible both after sunset and before sunrise.) Over the next several weeks, observers around the world focused in on the object. It reached a maximum brightness of magnitude 4.2 on February 22 and then slowly faded. By the beginning of March, Nova Cygni 1992 shone at 6th magnitude, and now it is visible only through a telescope.

Novae occur in close binary star systems in which one star is usually a white dwarf and the other a star evolving off the main sequence. As the evolving star expands, some of its hydrogen-rich envelope is drawn to the white dwarf. As this material accretes on the white dwarf's surface, its temperature increases until thermonuclear reactions begin. The reactions proceed explosively, creating the sudden brightening we see on Earth. At its height, a typical nova shines about 100,000 times brighter than the quiescent binary system. The system then returns to normal and matter again starts accreting on the white dwarf.



Jack Newton

Patrick Wiggins and Bruce Grim

**NOVA CYGNI 1992 SHINES** at 5th magnitude in northern Cygnus on the morning of February 26 (arrow, below). A closeup (inset) taken the next day shows the nova as the brightest object in the field.

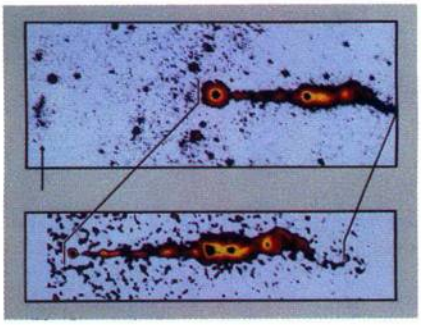
## M87 JET HAS A COMPANION

Recent optical images of the giant elliptical galaxy M87 show for the first time a faint jet pointing in the opposite direction to the galaxy's well-known optical and radio jet. The discovery of this counterjet raises questions about the nature of jets and what the jets say about conditions in active galaxies.

The new ground-based images, taken by two independent teams of astronomers (one led by Massimo Stiavelli of the European Southern Observatory, the other by William Sparks of the Space Telescope Science Institute), reveal an arc-shaped filament lying about 6,000 light-years east of M87's center. This feature coincides with a hot spot previously observed in the radio emission emanating from the M87 region. From the color and polarization of the feature, the astronomers deduced that the radiation is synchrotron emission — produced by electrons moving near the speed of light, radiating as they spiral around magnetic field lines — the same mechanism that produces the radio emission.

Most jets observed in quasars and radio galaxies appear one-sided. This is in striking contrast to the overall radio emission from these objects, which comes from twin lobes symmetrically placed around the quasar or galaxy.

Astronomers have developed three models to explain the asymmetry in the jets. First, the jets are two-sided but we see only one side because they move at



ESO

**A FAINT COUNTERJET IN M87** raises questions about the nature of the jets seen in radio galaxies. This first-ever optical image of the arc-shaped feature (arrow in top panel above) shows the counterjet is much fainter than the main optical jet on the other side of M87. (The giant elliptical galaxy has been subtracted from the center of the image.) A more detailed view of the main jet (bottom panel) shows individual knots to a resolution of 0.25 arcsecond.

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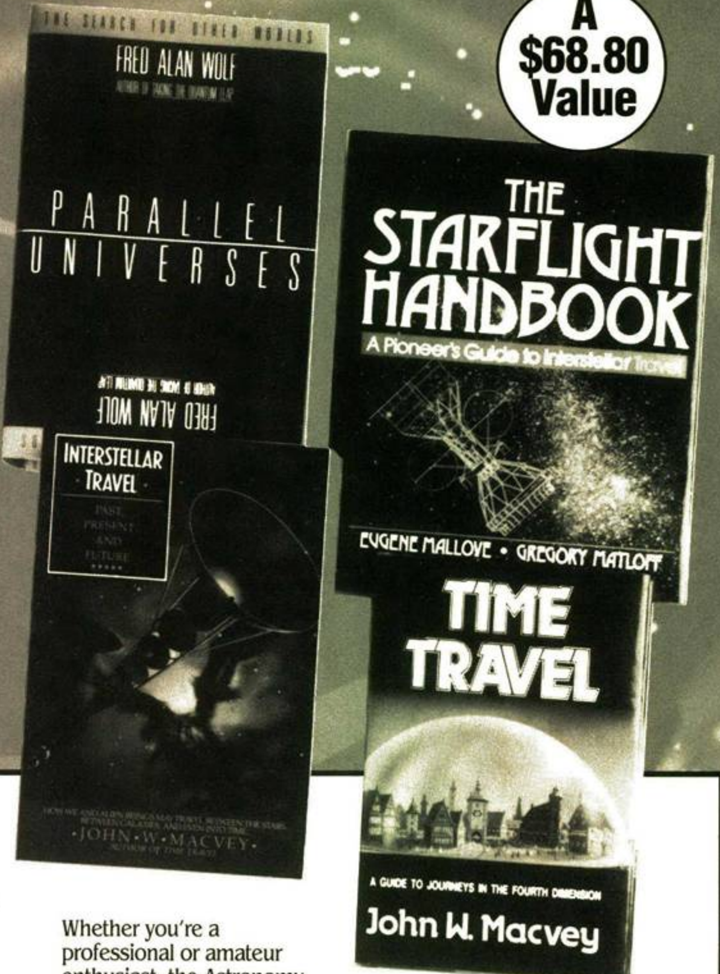
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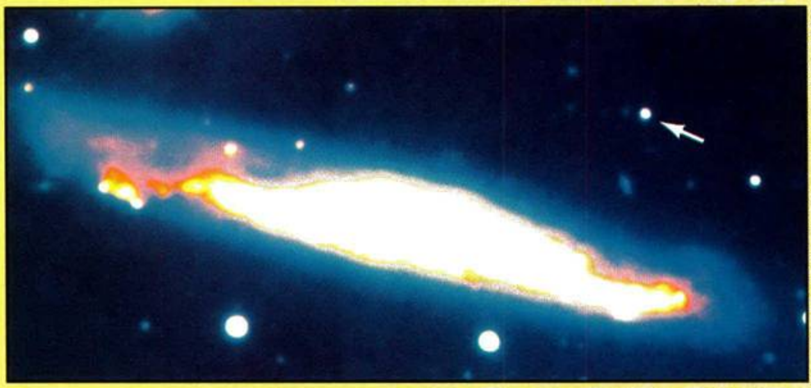


Womble et al. (*Astrophysical Journal*, March 20, 1992)

**PROBING QUASAR LIGHT** is becoming a new tool for studying the structure of galaxies. Astronomers have probed the bright galaxy NGC 3079 in Ursa Major by studying the light from a more distant quasar (marked by the arrow). Donna Womble, Vesa Junkkarinen, and Margaret Burbidge of the University of California at San Diego have determined that although the quasar at first glance appears separated from the main disk of NGC 3079, the quasar is actually shining through faint shells of gas blown away from the galaxy by clusters of stars in the process of forming. As the quasar's light passes through the galaxy's outer shells, certain wavelengths of light are absorbed by the galaxy. Analyzing the absorption in this and other chance alignments of quasars and galaxies, astronomers can learn more about the composition of the outer haloes of galaxies and the winds that blow material away from galaxies into space.

speeds near the speed of light. Einstein's special theory of relativity tells us that in such cases, the jet approaching Earth appears much brighter than the receding jet. In the second model, the jets are two-sided but only one side is energetic enough to be seen. And third, the jets are one-sided but alternate from side to side.

High-resolution radio observations of the jets in quasars confirm that the jet material moves at extraordinarily high speeds, strongly supporting the first model for quasar jets. The situation in radio galaxies, however, is more complex. Two types of radio galaxies exist — Type IIs have high energies and possess jets similar to those in quasars, while Type Is, like M87, have lower energies.

The new observations of M87 essentially rule out the model in which the jet switches from one side to the other. If the newly observed counterjet had switched off (and gone to the other side of the galaxy to form the bright jet seen there), the arc-shaped filament would continue shining for only about 1,500 years, a very short time in astronomical terms. The fact that the counterjet is visible provides strong evidence that it has been active for a long time.

But if not that model, then what? The observed motions in the jets of M87 and other Type I radio galaxies are nowhere near the speed of light. So to make the relativistic model work, astronomers need to explain how the overall flow in the jets can move at speeds near that of light while the features we see in the flow move much more slowly. Alternatively, astronomers must explain how the energetic electrons moving in the M87 counterjet fail to excite the surrounding interstellar medium, when the bright jet does so with no problem. Only more time, and more observations of radio galaxies, will bring us these answers.

## *SUPERNOVAE LITTER THE SKY*

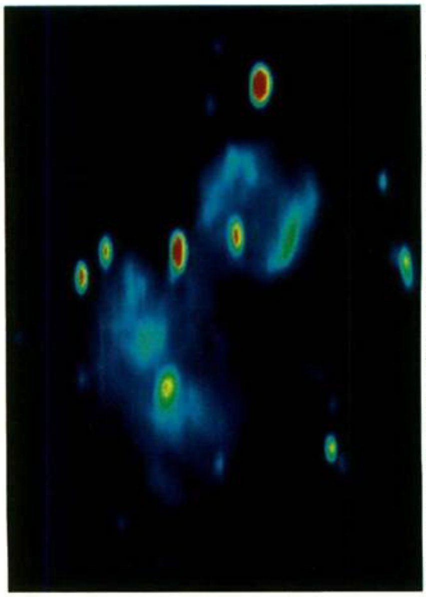
There could be many more ancient supernovae scattered around the Milky Way than astronomers have estimated. That's the conclusion of radio astronomers Andrew Taylor and Brad Wallace of the University of Calgary and Miller Goss of the National Radio Astronomy Observatory.

Using a radio telescope in Holland the team discovered 11 new supernova remnants in a selected region of the Milky Way, nearly doubling the number of these expanding debris clouds known in that region of the sky. Their research was reported in the March 1992 *Astronomical Journal*.

Using the Westerbork Synthesis Radio Telescope the team surveyed a 46° by 3° swath along the Milky Way through Cygnus and Aquila. Previous searches of the same area had turned up 15 supernova remnants. By extrapolating their number of new discoveries, the radio astronomers estimate there are at least 150 more ancient supernovae yet to be discovered in our Galaxy compared to 170 known remnants.

According to Taylor, the number of supernova remnants in the Milky Way could actually be closer to 500 or more. Taylor's estimate comes from the fact that even though radio astronomers had thoroughly searched this area of the sky, his team was able to nearly double the number of known remnants. Other parts of the sky have not been as thoroughly searched by previous surveys and are likely to contain many more undiscovered remnants.

The new-found number of supernova debris clouds is not a surprise but a relief to astronomers. Theories of how and why stars explode predict that we should see a lot more remains of old



Andrew Taylor and Brad Wallace (University of Calgary) and Miller Goss (NRAO)

**THE NEWLY DISCOVERED REMAINS OF A SUPERNOVA** called G59.5 +0.1 appear as a shell of radio-emitting debris at upper right. Astronomers have found evidence for twice as many such remnants in the Milky Way as previously thought.

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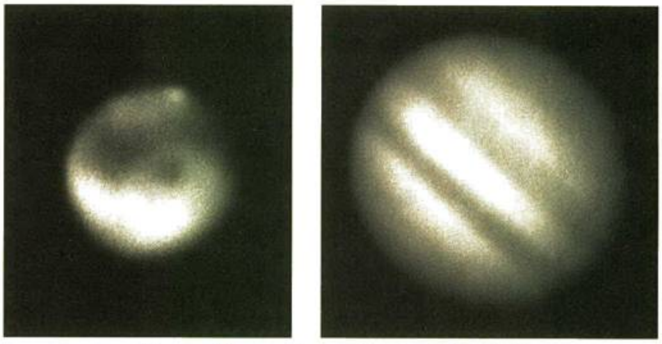

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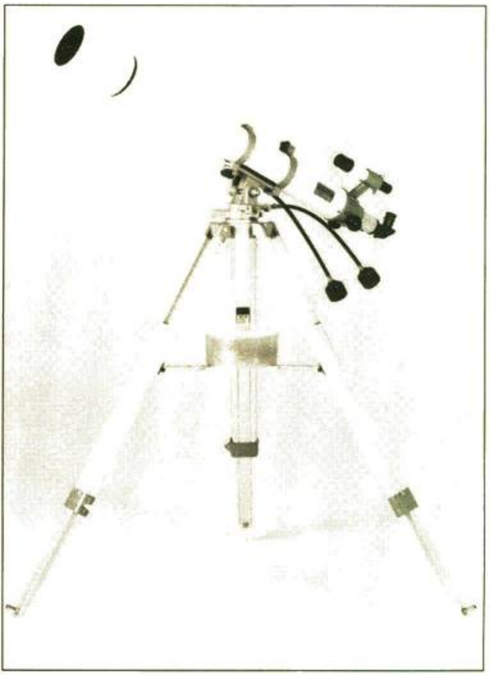

The 90mm Alt-azimuth Refractor (#3310) pictured, along with the 80mm unit (#3309), are excellent buys.

The 4-1/2" f/7.9 equatorial Newtonian telescope (#9117) as well as an Alt-azimuth unit (#9115) are very affordable.

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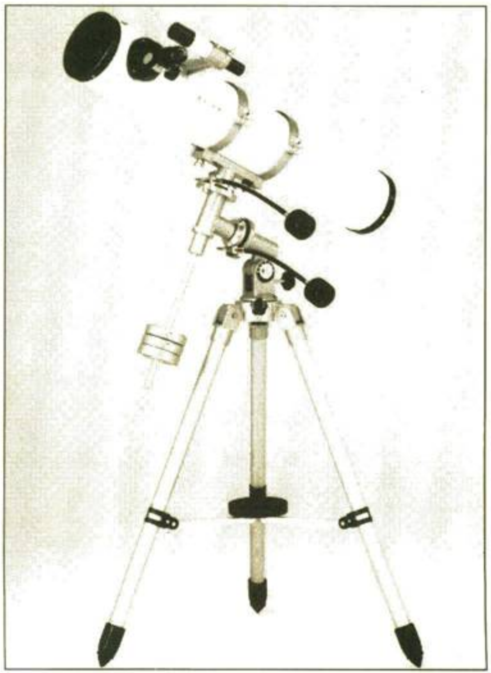

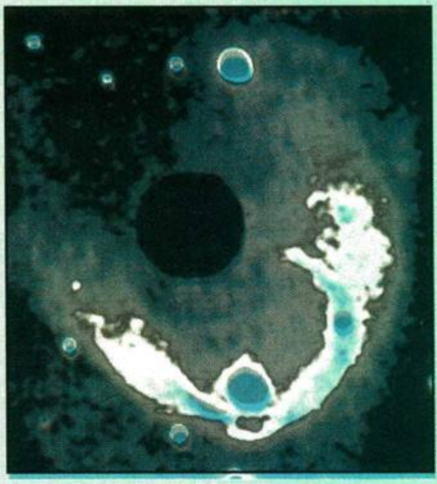

Hollis et al. (*Astrophysical Journal*, July 1992)

**MOVING AT SUPERSONIC SPEEDS** through interstellar gas is a star known as 0623+71. Though its identity as a mere catalog number belies the fact, this star is actually a fascinating object — an example of a cataclysmic variable. The 12th-magnitude object consists of a pair of stars, one of which is a white dwarf. Material from the dwarf's companion star falls onto the hot surface of the dwarf causing an occasional eruption of energy — from Earth the star periodically increases in brightness. In the case of 0623+71, the pair is also emitting a wind of gas that blows out from the stars. But 0623+71 is moving so fast through the surrounding interstellar gas that the star's outflowing wind is being blown back around the star, forming a wake in space. That's the conclusion of the research team of Jan Hollis, Ronald Oliverson, and Walter Feibelman of the Goddard Space Flight Center, along with Mark Wagner of Ohio State University. They conclude that the leading edge of the material from 0623+71 forms a bow shock, just like the air that piles up in front of an aircraft flying at supersonic speeds. In this visible-light image taken with the 36-inch telescope at Kitt Peak, the star appears as the large blob near the apex of the bow shock.

supernovae than we do. The doubling of known remnants "fills a gap and confirms our expectations," says Andrew Taylor. "However, many of the remnants we are finding are smaller and fainter than expected." Some may simply be far away but others, the team suspects, are nearby. Because the debris clouds fade as they expand and age, small nearby remnants should be young and bright. The faintness of some of the new remnants prompts Taylor to suggest, "We may have to rethink the energetics of a supernova explosion or the way supernovae evolve after the initial explosion."

## HOW BIG IS PLUTO?

Pluto's size has long been an elusive value. The recent series of eclipses of Pluto by its moon Charon yielded a diameter for Pluto of 2,300 kilometers. But writing in the March 1992 *Astronomical Journal,* James Elliot and Leslie Young, both of MIT, suspect this figure may be too low. They feel that a darkening of the edge of Pluto's disk may have caused astronomers to underestimate Pluto's true diameter.

By watching Pluto pass in front of a star and recording the length of time the star's light disappears, astronomers could determine Pluto's precise diameter. Theoretically.

On June 9, 1988, astronomers aboard the Kuiper Airborne Observatory observed just such a stellar eclipse by Pluto. But determining the diameter of Pluto from this event has been complicated by a key factor — Pluto's atmosphere. The presence of a tenuous atmosphere surrounding Pluto means the edge of Pluto is actually fuzzy. Finding out where the true surface lies requires an accurate model of how deep the atmosphere is, what it's made of, and how opaque it is, tough to do for a planet 4.5 billion kilometers away.

To calculate Pluto's size, Elliot and Young worked with two models of Pluto's atmosphere: one with an atmosphere that is clear and only a few kilometers thick, and one with a haze layer that starts at the top of a much deeper atmosphere and extends down to a surface that lies 100 kilometers or more below the top of the haze.

Applying the clear-air model to the 1988 occultation data, they estimate that Pluto's true diameter could be 2,412 kilometers. If the atmosphere is hazy, the same data yields a diameter of no more than 2,362 kilometers.

## NEW ASTEROID DISTANCE CHAMPION

Ever since Charles Kowal discovered the asteroid/comet Chiron in 1977, astronomers have wondered if any other minor planets exist in the outer solar system. The answer finally came 15 years later, in January 1992, when D. L. Rabinowitz discovered a slow-moving, 17th-magnitude object on an image taken with the Spacewatch telescope in Arizona. As the fourth asteroid discovered in 1992, it received the preliminary designation 1992 AD.

It took three weeks of observations before astronomers could calculate the orbit of 1992 AD. When they did, they found the new object had a large and highly eccentric orbit. When closest to the Sun, as it was in mid-1991, 1992 AD lies just inside the orbit of Saturn. It then heads out to beyond the orbit of Neptune, some 2 billion kilometers farther from the Sun than Chiron at its most distant. In all, it takes 1992 AD 93 years to orbit the Sun once.

Preliminary measurements show 1992 AD has a diameter of approximately 160 kilometers and possesses no atmosphere. This differentiates it from Chiron, which over the past few years has developed an atmosphere as

ESO

**FAR FROM THE SUN** lies the newly discovered asteroid 1992 AD — the asteroid with the largest orbit yet seen. The telescope taking this photo tracked the asteroid, so it appears round while the background stars are trailed.

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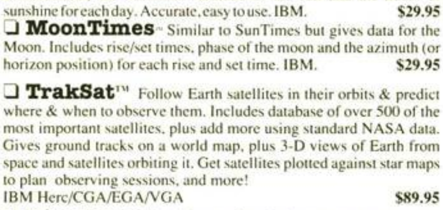

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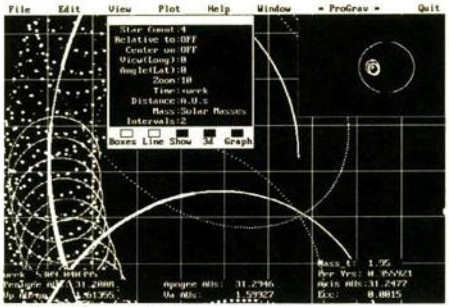

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Relative to:OFF
 Center on:OFF
View(Long):0
Angle(Lat):0
      Zoom:10
  Distance:A.U.s
      Mass:Solar Masses
 Intervals:2
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Mass_t:  1.95
Apogee Alt:  31.2946        Axis Alt:31.2477
Va Alt:      1.59927        Ecc:      0.0015
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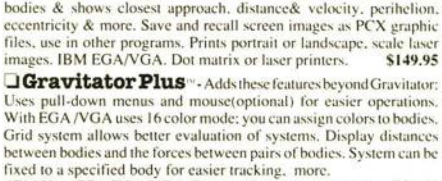

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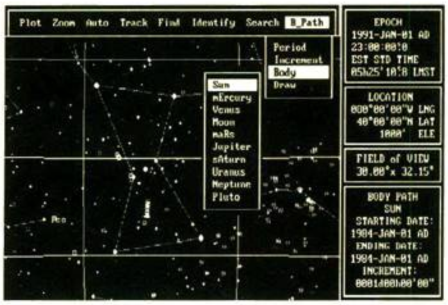

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EPOCH
1991-JAN-01 AD
23:00:00:0
EST STD TIME
05h25'10:8 LMST

LOCATION
000°00'00"W LNG
40°00'00"N LAT
1000'  ELE

FIELD of VIEW
30.00°x 32.15°

BODY PATH
SUN
STARTING DATE:
1984-JAN-01 AD
ENDING DATE:
1984-JAN-01 AD
INCREMENT:
0001d00h00'00"
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Partial Solar Eclipse
Magnitude: 0.170  Obscuration:  0.3x
LAST CONTACT
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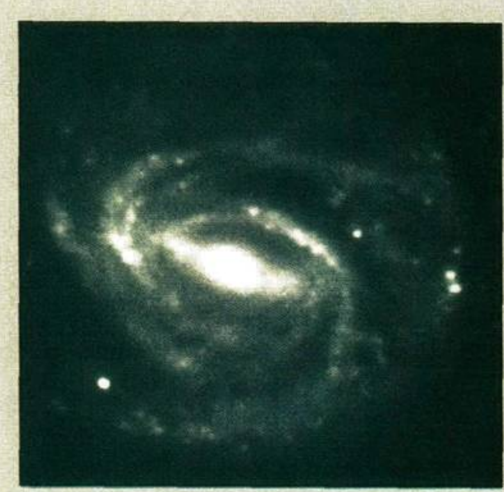

ESO

**SUPERNOVA 1992C IN LEO** appeared in January as a 16.5-magnitude object in NGC 3367, a barred spiral galaxy located about 200 million light-years from Earth. This type II supernova resulted from the explosion of a massive star that ran out of its nuclear fuel. Hans van Winckel and Massimo Della Valle, astronomers at the European Southern Observatory, used a 2.2-meter telescope to take this CCD image, which shows the bright supernova in the bottom left corner.

it comes closer to the Sun.

The discovery strengthens the belief held by many astronomers that a large number of objects lies outside the orbit of Saturn. With the recent proliferation of new and more powerful observing techniques, we should soon know if that is, in fact, the case.

## TIME TO KILL

Earth's rotation is slowing down, and to compensate for this lagging motion, June will be one second longer than normal. This leap second, announced by the International Earth Rotation Service in February, will keep calendar time in close alignment with international atomic time. To accomplish this change,

## Amateur News

# ASTRONOMY CO-HOSTS UNIVERSE 92

A weekend astronomy fair and product expo is coming to the midwest. Co-sponsored by ASTRONOMY magazine and the Astronomical Society of the Pacific, UNIVERSE 92 promises to be an exciting two days of talks, seminars, exhibits, and product demonstrations. On Saturday, June 20 and Sunday, June 21, several hundred amateur astronomers are expected to converge on the University of Wisconsin campus in Madison. The weekend's activities are open to anyone with an interest in astronomy — sessions will be geared to a range of interests, with the focus on non-technical talks and introductory seminars.

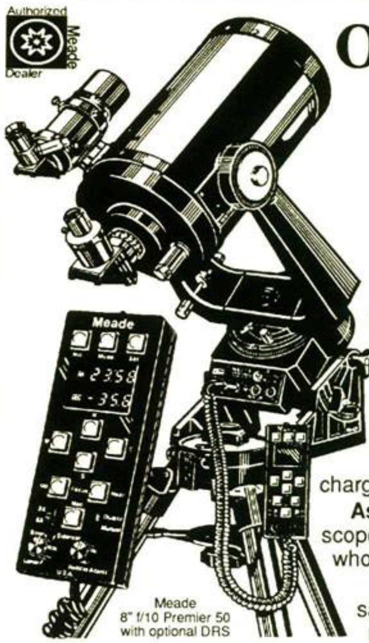
One of the highlights will be displays of telescopes, accessories, and computer software from many of the manufacturers of today's popular equipment. Manufacturers' representatives will be on hand to demonstrate their products and answer questions about current and upcoming models.

The program schedule for both days will be filled with talks by an impressive lineup of well-known scientists, science writers, and amateur astronomers. Some of the speakers and their topics include:

- Richard Berry (former editor of ASTRONOMY) — Image Processing for the Amateur
- John Brandt (University of Colorado) — Comets after Comet Halley
- Deborah Byrd (ASTRONOMY columnist and writer of "Star Date" and "Earth and Sky") — Astronomy on the Radio
- Eric Chaisson (Space Telescope Science Institute) — The Latest Science and Images from Hubble
- Frank Drake (SETI Institute) — Life Elsewhere in the Cosmos: SETI on the Threshold
- Alan Dyer (Associate Editor of ASTRONOMY) — Selecting the Right Telescope
- Dave Eicher (Associate Editor of ASTRONOMY) — The Joys of Deep-Sky Observing
- Ronald Evans (noted amateur astronomer from Australia) — Hunting Supernovae
- Timothy Ferris (author of *Galaxies, Coming of Age in the Milky Way*, and *The Mind's Sky*) — Is the Big Bang In Trouble?
- Andrew Fraknoi (ASP) — Astronomy vs. Astrology
- Donald Goldsmith (author of *The Astronomers*) — Asteroid Collisions, Dying Dinosaurs, and the Deathstar
- David Crawford (Kitt Peak) — Light Pollution: Thief of the Night
- Tom Hunt (Art Director of ASTRONOMY) — Space Art: Renaissance to Cosmos
- William Kaufmann (San Diego State University) — Black Holes and Warped Spacetime
- Ed Krupp (Griffith Observatory) — Star Myths and Stories
- Jack Newton (noted amateur astronomer and author) — Astrophotography
- Vera Rubin (Carnegie Institution) — Galaxies and Dark Matter
- Stephen Saunders (Project scientist for the Magellan mission) — Venus Unveiled
- Maarten Schmidt (Caltech) — Quasars: Distant Probes of the Universe

Other speakers are being added to the schedule. There will also be a Saturday night star party hosted by the Madison Astronomical Society, as well as a Meet-the-Author book-signing table, and lots of door prizes. Registration for the entire weekend is only $20, or $12 for a single day. Seniors and students can get in for $6 a day or $10 for the weekend. Those wishing to attend UNIVERSE 92 can register in advance or at the door. Conference organizers have arranged for inexpensive hotel accommodations in Madison and dormitory-and-meal packages on the University of Wisconsin campus. Special rates on air travel and car rentals are also available.

To receive a registration packet, write to the Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112, or call (415) 337-1100 between 9 a.m. and 5 p.m. Pacific Time.



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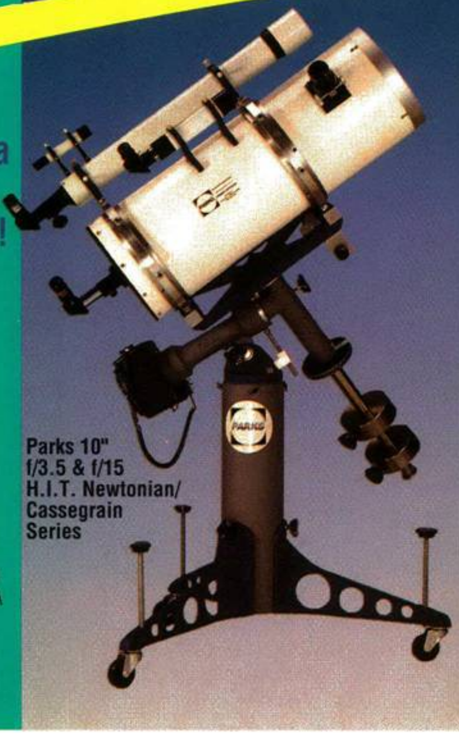

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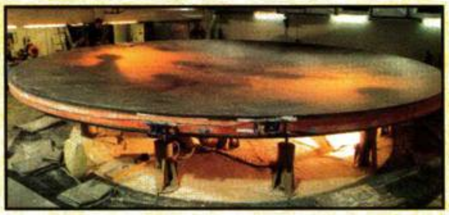

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## Space News

## CRRES: MISSION ACCOMPLISHED

A satellite that created several artificial aurorae has finished its research program. The Combined Release and Radiation Effects Satellite (CRRES) operated for 15 months, three months longer than planned. A systems failure in December 1991 ended the CRRES mission.

During its lifetime, CRRES released 24 canisters of barium, calcium, and lithium. Sunlight ionized the chemicals and created glowing clouds that acted as visible tracers of Earth's magnetic field lines.

In March 1991, during a major bombardment of particles from the Sun, CRRES detected the formation of a third radiation belt around Earth. With an altitude of 6,000 to 7,000 kilometers, the new belt formed between the two existing belts discovered in the late 1950s.

Los Alamos National Laboratory

**GREAT BALLS OF GREEN FIRE** were created by the CRRES mission throughout its 15-month lifetime. On July 22, 1991, the satellite produced this brilliant cloud of barium gas, seen here setting behind a low-lying cloud bank.

## STILL AMAZING AFTER ALL THESE YEARS

On Monday, March 2, the venerable spacecraft Pioneer 10 marked 20 years of exploring space. Launched March 2, 1972, Pioneer 10 was the first spacecraft to fly past Jupiter, a destination it reached in December 1973. Ten years later Pioneer 10 became the first spacecraft to pass beyond all the planets. On its 20th anniversary in space, Pioneer 10 was 5 billion miles from Earth, nearly twice as far from the Sun as Neptune or Pluto, making Pioneer 10 the most distant manmade object in history.

Eight of Pioneer's 10 instruments continue to function, though it takes 7.5 hours for a signal from Pioneer to reach Earth. When the signal does get here, its strength has dwindled to 4.2 billionths of a trillionth of a watt.

The spacecraft is now probing the outer limits of the Sun's extended atmosphere, the heliosphere. "If we're lucky," commented Pioneer high-energy particle experimenter James Van Allen, "we may break out of the heliosphere into the interstellar gas before we lose contact with Pioneer around the year 2000. This would be the first direct measurement of true interstellar space."

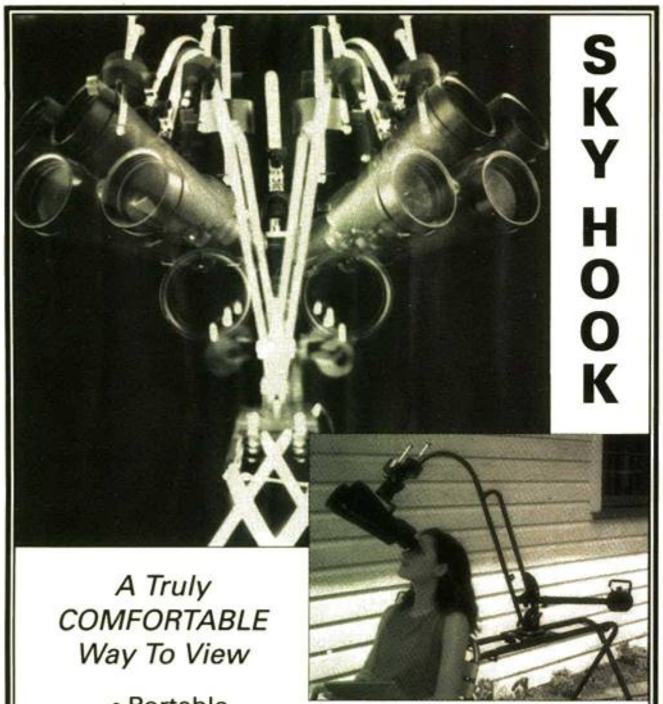
Pioneer experimenters are also using the 570-pound spacecraft to search for Einstein's predicted gravity waves and for the gravitational effects of a possible 10th planet.

## VISIT TO A COMET CANCELLED

In early February, NASA was forced to cancel the Comet Rendezvous Asteroid Flyby mission that had been planned for launch later this decade. The space probe was to have been a key element in NASA's planetary program for the next 10 years and would have conducted close examinations of an asteroid and a comet, examples of primitive solar system objects.

The good news in the NASA budget crunch is that the other half of the planned mission, the Cassini space probe, was saved. Cassini will orbit Saturn and drop an instrumented probe into the atmosphere of Saturn's major moon, Titan. The mission is now set for a 1997 launch, the last chance for the Jupiter gravity assist Cassini needs to get to Saturn.

In a press release to the science community, Wes Huntress, Director of NASA's Solar System Exploration Division, stated, "I am satisfied that the agency fought hard for the CRAF/Cassini program. Loss of the entire program was a real possibility. The Division will examine options to reconstitute a comet mission." □



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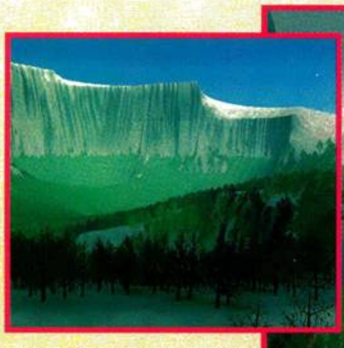

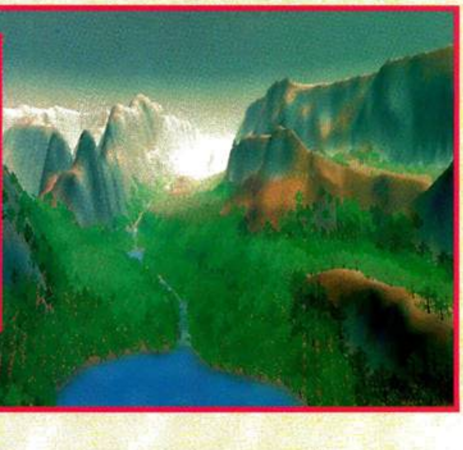

Above: Olympus Mons, Mars
Right: Valles Marineris, Mars
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RELATIVITY & TIME TRAVEL

# TUNNELS THROUGH TIME

Einstein's general theory of relativity leaves open the extraordinary possibility that one day we might travel through time.

by Barry Parker

KIRCHMEIER 92

All illustrations ASTRONOMY: Phil Kirchmeier.

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Imagine what it would feel like to be catapulted hundreds, even thousands of years into the future, or to travel into the misty past to visit your ancestors. Ever since H. G. Wells penned his classic *The Time Machine* nearly one hundred years ago, humans have dreamed of breaking the bonds of time. But will these dreams ever become reality? In just the last few years, scientists looking into this question have reached a startling conclusion — time travel may indeed be possible. The time "machine" needed to pull off this fantastic voyage is called a wormhole, a tunnel of warped space-time predicted by Einstein's general theory of relativity.

Before we can travel through time, however, astronomers and physicists have to learn much more about both space and time. Fortunately, we have some control over space: we can move to any point in our immediate neighborhood with little difficulty. Time, on the other hand, appears uncontrollable. As much as we might like to slow it down on occasion, we can't. Nor can we speed it up. It ticks away relentlessly and at the same monotonous rate no matter what we do.

Isaac Newton was convinced that time was absolute, that it ran the same for everyone throughout the universe. But in 1905, Albert Einstein proved Newton wrong. His special theory of relativity showed that time passes at different rates for different observers. If you travel at a speed close to that of light relative to some friends of yours, your friends would perceive your time as running slower than their own.

This was a significant breakthrough. Suddenly, traveling through time and voyaging to the stars seemed possible. Astronauts who leave Earth and travel close to the speed of light could, by their reckoning, cover light-years in mere days. Upon returning to Earth, however, the astronauts would find that thousands of years had elapsed. In effect, they would have traveled both to the stars and thousands of years into the future.

Einstein's special theory of relativity opened our eyes to some of the mysteries of time. But it was a restricted theory, applying only to straight-line motion at a constant speed. Einstein wasn't satisfied with this. He wanted a theory that applied to all types of motion and in particular to accelerated motion. For ten years he struggled to extend the theory and, finally, in 1915 he succeeded. But his new theory did more than just generalize special relativity to accelerated motion; it also was a theory of gravity. Acceleration and gravity, it turns out, are intricately linked.

### Warped Space and Wormholes

Einstein's general theory of relativity, as it is called, provides an important insight into the nature of space and time: gravity profoundly affects them. But because matter creates gravity, matter controls space and time. Matter curves space; in other words, it warps or distorts it. As the density of matter in a

**A renowned scientist attempts to enter a black hole wormhole, but tidal forces stretch him to the breaking point.**

region of space increases, the curvature of the space increases and this, in turn, slows the rate at which clocks run. If the space is curved severely enough, in fact, clocks will actually stop. For many years, physicists called the region where clocks stop the "forbidden sphere."

As scientists mathematically explored this forbidden sphere, they were dismayed to learn that its interior was cut off from the rest of the universe. General relativity could say nothing about the conditions inside it. Furthermore, the space leading down to the sphere was twisted into a bizarre funnel. No matter what direction you approached the sphere from, you would appear to be in a tunnel made of curved space. While analyzing the space-time geometry of the forbidden sphere, Einstein and a colleague, Nathan Rosen, showed that the tunnel had a mirror-image tunnel attached to its other end. It was like a "wormhole" in space with two entrances.

What would happen if you tried to pass through a wormhole? Einstein concluded that you would have to end up in another universe. After all, if a distant observer sees your clock stop as you reach the forbidden sphere, then you would see the time in the rest of the universe move infinitely fast. To put it another way, the entire future of the universe would pass before your eyes as you descended into the wormhole. Einstein found the idea of passing into another universe repugnant. Fortunately, the details of the calculations gave him a way out — it would take a speed greater than that of light to pass through the wormhole, making it impassable.

Whether or not you could pass through these wormholes and forbidden spheres begged the question of whether they existed and, if so, how they arose. Because matter curves space, the places to look would be regions of high densities, densities far beyond those found on Earth.

One possibility stems from the fact that stars evolve — they are born, live for millions or billions of years, then die. And when they die, many collapse in on themselves. If a star has enough mass, it can collapse so far that it becomes cut off from our universe.

Robert Oppenheimer of the California Institute of Technology was the first to use Einstein's theory to study a star's collapse. He found that a star would collapse forever, but as it passed a particular radius (called the gravitational radius), it would leave a black sphere — a black hole in space. The collapse would not stop there, however, but would continue until all the star's matter occupied a point, or "singularity," at the center of the black hole.

The surface of a black hole is known as the event horizon. It is a one-way surface — once inside it, you cannot escape. To get out you would have to travel faster than the speed of light, which relativity tells us is impossible.

The simplest type of black hole is named after German astronomer Karl Schwarzschild, who first described it in 1916 using Einstein's theory. A Schwarzschild black hole warps the space surrounding it into a wormhole, which theoretically could act as a "subway" to distant points in the universe or to different times. These wormholes did not bring the dream of space or time travel any closer to reality, however, because as Einstein showed, you would have to travel through such a wormhole at a speed greater than that of light.

### Black Holes Galore

The same is not true for the wormholes associated with more complex black holes. A Schwarzschild black hole is simple because it possesses neither spin nor charge. When a spinning star collapses (and most stars do spin), the black hole created also spins. In 1963 New Zealand mathematician Roy Kerr solved the equations for spinning black holes, which are now called Kerr black holes. Besides mass and spin, electric charge is the only other property not crushed out of existence when a black hole forms. In the late 1910s, H. Reissner from Germany and G. Nordstrøm from Denmark solved the equations for a charged black hole, which is now called a Reissner-Nordstrøm black hole. The only other type of black hole possible is one with both charge and spin. This type was solved by Roy Kerr and E. Newman and is known as a Kerr-Newman black hole.

The collapse of a massive star is just one way to form a black hole. Stephen Hawking of Cambridge University has shown that the extreme conditions in the big bang explosion that gave birth to the universe might also have created black holes. If the big bang was inhomogeneous, black holes could have formed when pockets of matter were crushed under the tremendous pressures present. These primordial black holes would be far different from stellar-collapse black holes because of their incredibly small size — a typical one might have a mass of a few billion tons packed into a sphere no larger than an atom. At the other end of the size spectrum, astronomers suspect that the cores of some galaxies harbor gigantic black holes with masses millions or billions of times that of the Sun and diameters the size of our solar system. All stellar-collapse black holes, on the other hand, contain a few solar masses in a sphere a few miles across.

Scientists studying the physics of the four types of black holes made an unexpected discovery — it's possible to pass through the wormhole of any non-Schwarzschild black hole at a speed *less* than that of light. Perhaps wormholes can be used, after all, as time machines and as passageways to the stars. Scientists have encountered and overcome a host of theoretical objections to time travel since they learned wormholes could be traversed. But before the first adventurous time travelers journey through a wormhole, scientists will have to overcome many more obstacles.

One of the biggest conundrums facing physicists exploring the possibility of time travel is whether

time travelers could change history. Consider the grandfather paradox. Assume for a moment that wormholes will one day allow humans to travel through time. In theory, we could have a wormhole that begins near Earth and twists through space-time so that it also exits near Earth. If you passed through this wormhole, you would return to Earth either many years in the future or many years in the past.

### A Death in the Family

Now imagine finding out that your grandfather was a cruel person who destroyed many people's lives. To protect your family name, you decide to travel back in time through one of these wormholes to do away with the nasty gent. If time travel is possible and you manage to rub out your grandfather before your mother or father was born, then presumably you were never born either. But if you were never born, you couldn't have traveled back to rid the world of this person in the first place.

Let's look at the problem from a different point of view. Assume you went into a time tunnel at 11:00 a.m., passed through it, and returned to roughly the same point on Earth at 10:55 a.m. the same day. If so, you would see yourself getting into your spaceship to leave. You could then run over to yourself and say "Hello." Indeed, you could even stop yourself from going into the tunnel. In fact, if you actually went back in time and saw yourself leave, then you should have seen yourself watching you leave in the first place. After all, it was just a replay of what happened earlier.

You can imagine dozens of similar paradoxes along the same lines. They all violate what is called the causality principle, which says that the effect of something always comes after its cause. If a pitcher throws a baseball across home plate and a batter hits it, common sense says that the ball was not hit before the pitcher delivered. The idea that effect can come before cause is irrational to the human mind and goes against common experience.

As strange as it may seem, scientists are seriously asking whether it is possible, in principle, to violate causality. If time travel is somehow possible, it seems likely that causality could be violated. If, in fact, causality cannot be violated, then time travel into the past may be prohibited. Even if causality can't be violated, we might

**A time traveler journeys into the past and kills his grandfather. Does the traveler cease to exist and, if so, how did he kill his grandfather?**

be able to travel back in time as long as we don't interfere with the past in any way. Though not as glamorous as tinkering with history, such time travel still would be exhilarating beyond imagination.

Beyond the paradoxes time travel presents, strong physical constraints could keep humans from using the wormholes belonging to black holes as time machines. Shortly after wormholes were envisioned, theorists discovered that they are unstable. If a spaceship attempted to voyage through one, the wormhole would pinch off, crushing the ship and crew. And even if the ship could somehow pass through to reach a distant point in the universe, it would not be able to make the return trip. Because of a black hole's event horizon, wormholes offer only one-way passage. To get back to Earth, time travelers would have to find another wormhole nearby — a remote possibility, at best. (And this assumes that the travelers know precisely where each wormhole exits.) In all probability, our intrepid explorers would never return to their starting point.

If that isn't bad enough, time travelers might not even make it into a theoretically traversable wormhole. The primordial black holes described by Stephen Hawking would stop them in their tracks. Hawking showed that these tiny black holes actually emit particles and radiation. Particle pairs created from the black hole's energy spontaneously form in the vacuum near the event horizon. If a spaceship approaches this region to access the wormhole, this radiation would prove lethal to the ship's occupants. Fortunately, this is a serious problem only if the black hole is extremely small.

### A Tidal Wave of Problems

But the wormholes linked to stellar-mass black holes create their own set of problems. If a spaceship approached one of these wormholes, severe tidal forces would pull the ship apart, along with all its inhabitants. These tidal forces are the same as the force that creates tides on Earth. The Moon's gravity pulls on the near side of our planet stronger than on the center and on the center stronger than on the far side. The net effect is that the Moon stretches Earth and its ocean waters into an oblong shape.

Tidal forces arise anywhere there's a source of gravity. Earth creates minuscule tidal forces in your own body, pulling stronger on your feet than on your head. Fortunately, the difference is so small that you can't feel it. If you stood on the surface of a much denser object, however, the tidal force would be significant. Near the surface of a neutron star, the force would be strong enough to pull you apart. And a stellar-mass black hole is even more dense than a neutron star, so you wouldn't survive even a close approach to its event horizon.

Obviously, no spaceship or passengers would make it as far as the entrance of a wormhole connected to a stellar-collapse black hole. But tidal forces are not as big a problem in the vicinity of more massive black holes. As the mass of the black hole increases, the tidal forces at its event horizon decrease. That's because the radius of the event horizon increases with the black hole's mass and tidal forces fall very rapidly with increasing distance from the central singularity. For a black hole of 10,000 solar masses, the tidal forces at its event horizon would be moderate and a human could pass through the horizon without discomfort.

Safe passage isn't the only criterion for future time travelers, however. Astronomers suspect that black holes with masses of 10,000 solar masses or more lurk only in the cores of some galaxies. This means that the nearest candidate for a black hole wormhole with moderate tidal forces lies in the core of our Galaxy. But black hole wormholes allow only one-way travel, so to have any hope of returning to Earth, the time travelers also need access to other wormholes. That means journeying into the cores of other galaxies. Though we need wormholes to travel long distances through space and time, the wormholes connected to massive black holes are separated by millions of light-years. Even if these wormholes offered the only hope for time travel, it wouldn't make much sense to use them.

In many ways it looked hopeless. Not only did the possibility of time travel raise troubling theoretical paradoxes, but also the doorways to time travel — wormholes harbored by black holes — seemed shut by either lethal forces or enormous and essentially unconquerable distances. The problems proved so severe that scientists soon abandoned the idea of time travel. As far as they were concerned, time travel by way of black hole wormholes would forever remain beyond the reach of mankind.

But that's not the end of the story. A glimmer of hope appeared in the mid-1980s when scientists working with Einstein's equations of general relativity found a way around the physical problems. If any wormholes exist apart from black holes, they conceivably can be made traversable.

### Have Wormhole, Will Travel

The solution to the many problems came about almost by accident. In the early 1980s, Carl Sagan of Cornell University began writing his science fiction novel *Contact*. In the novel, heroine Ellie Arroway detected a radio signal from the vicinity of the star Vega. With some help, she managed to break the code and translate the message. The code contained instructions for building a "machine," a machine that eventually took Ellie and several of her colleagues to a planet near Vega.

In the original version of the book, Sagan used a wormhole associated with a black hole to get the group to Vega. As a scientist, he wanted to be sure that the science presented in the novel was as accurate as possible. He sent the manuscript to one of the foremost black hole experts in the world, Kip Thorne of the California Institute of Technology, and asked him to look it over.

Thorne was disturbed when he saw that Sagan

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had used a black hole wormhole to transport the crew. Though Thorne knew the problems associated with these wormholes, he still wanted to help Sagan. So he wrote down Einstein's equations and began looking for a solution others had overlooked — a solution that might allow time travel. And he found one. The solution was so simple he wondered why no one had noticed it before. Einstein's equations predicted that you could get around the pinch-off effect by using a wormhole that existed by itself and not in conjunction with a black hole. (Though this wormhole, by itself, would not be a time machine.) He sketched out the solution and left it to one of his students, Michael Morris, to fill in the details.

Pinch-off was not the only problem the theorists had to overcome. To be traversable, the wormhole had to possess several properties. Thorne and Morris listed them: the wormhole had to have small tidal forces; it had to provide two-way passage, which meant it could not have an event horizon; the time it took to travel through the wormhole had to be reasonable, from the point of view of both the time traveler and the people outside the wormhole; any radiation effects had to be minimal; and the wormhole had to be constructed with reasonable materials and within a reasonable period of time.

The most serious problem was stopping the wormhole from pinching off. Thorne came to the conclusion that some sort of matter would have to be threaded through or applied to the surface of the wormhole. This wouldn't be just any sort of matter either — it would have to produce an outward pressure strong enough to contain the inward squeezing of the wormhole. Thorne found a solution to Einstein's equations that allowed him to do this.

Thorne and Morris soon devised a solution that met all the requirements on their list. The only problem is in the nature of the material needed to line the wormholes. It can't be ordinary matter. In fact it has to be very extraordinary — "exotic" matter as physicists call it. The inward pressure on the tunnel is so great that the matter needed to counteract this pressure has to exert an outward tension comparable to the pressure at the center of a neutron star. This means the tension has to be greater than the total density of mass energy of the wormhole itself. Nothing on Earth even approaches this. However, thousands of years from now the production of such a material might be routine.

It appears possible, at least in principle, that one day humans will be able to traverse one of these wormholes. But that, by itself, won't transport us through time. We still have to make the wormhole into a time machine.

The germ of the idea for doing this came from Thomas Roman, a theorist at Central Connecticut State University. At a conference in 1986, he talked to Morris and learned about his and Thorne's work on wormholes. Roman mentioned that special

**An Earthbound twin ages faster than a twin who embarks on an ultrahigh-speed voyage. If we learn how to accelerate a wormhole that fast, it will turn into a time machine.**

relativity could point the way to transforming wormholes into time machines. At first Morris didn't think this was possible, but the more he thought about it, the more he liked the idea. Morris applied the tenets of special relativity to the concept of wormholes and discovered that someone entering two wormholes, one after the other, could travel back in time. He showed his calculations to Thorne and together they refined the idea.

Eventually the two found that a single wormhole could be transformed into a time machine capable of transporting people into both the past and future, depending on which direction their spaceship traveled. The key to their discovery lay in what special relativity says about the rate of running clocks. If one clock moves relative to another at constant speed, an observer at rest near the stationary clock sees the moving clock tick off seconds at a slower rate. This leads to one of relativity's more famous results — the twin paradox. Imagine a brother-and-sister set of twins who decide to test Einstein's special theory. While the brother stays at home, the sister hops aboard a spaceship that rockets her away at a speed close to that of light. When she returns to Earth, she finds her twin has aged much more than she has, with the exact difference depending on how fast she traveled and for how long.

### A Feasible Time Machine

Thorne and Morris, together with Ulvi Yurtsever, another of Thorne's students, discovered that the two mouths of a wormhole could act in much the same way as the twins. (To an outside observer, the mouth of a wormhole would appear to be an ordinary object.) The theorists found that if one of the mouths moved off into space at high speed and then returned to a point near the other mouth, the wormhole would become a time machine.

To understand how this is possible, consider clocks both inside and outside the mouths of a wormhole. A clock just outside the stationary mouth does not move relative to one just inside the mouth, so they will show the same time. By the exact same reasoning, a clock just outside the moving mouth will show the same time as a clock just inside the moving mouth. But in the same way that a moving twin ages more slowly than a stay-at-home twin, the clocks near the moving mouth will show an earlier time than the clocks near the stationary mouth. Even after the moving mouth returns to the vicinity of the stationary mouth and comes to rest, the clocks will forever read differently.

So, if you enter through the mouth that has moved and exit through the stationary mouth, you will go back in time. You will come out of the second mouth before you entered the first one. In the same way, if you enter through the stationary mouth and exit through the mouth that has moved, you will go into the future.

As in the case of the twin paradox, the amount of the effect depends on how fast and for how long the moving mouth traveled. For a significant effect, however, you have to get the mouth up to a speed near 99 percent that of light — obviously a task reserved for advanced civilizations that have mastered space travel and, presumably, the production of the exotic matter needed to line the wormhole in the first place. One way they might attempt this is with a large asteroid that gravitationally attracts the wormhole's mouth. Start the mouth moving toward the asteroid, then accelerate the asteroid to great speed while keeping the mouth just out of reach. Another way would be to put some electrical charge on the wormhole, then use an oppositely charged object to attract it.

Although time travel is possible with a wormhole of this type, remember that the clock at the moving mouth is just slowed down relative to the clock at the stationary mouth. Because of this, you could not travel back in time any further than the day the time machine was created. If you want to go back further, you have to hope that some ancient, advanced civilization has already created wormhole time machines — as happened in Sagan's novel.

So far we've been talking about traversable wormholes as if they are fairly easy to make. They aren't. Unless we want to count on some hypothetical advanced civilization that's already built a galactic transit system, we need to find some other way to get a traversable wormhole. In their paper on wormholes, Morris, Thorne, and Yurtsever suggest a method. "One can imagine an advanced civilization pulling a wormhole out of the quantum foam and enlarging it to classical size," they write.

The quantum foam they refer to is a foam of space and nonspace — a fluctuating region filled with wormholes that exists on a scale much smaller than atoms. Although no theory directly postulates this foam, its existence seems to be a natural outgrowth of what we know about the theory of quantum gravity. And most physicists are convinced that the quantum foam exists.

Even if it does exist, we must ask if we will ever be able to enlarge and stabilize a wormhole out of this foam. We've overcome many problems just to see a way to travel through time, but formidable problems remain. Obviously, time travel isn't around the corner. But science and technology are advancing rapidly so it's difficult to imagine what we will be capable of thousands of years from now. At the present time scientists are not concerned about whether time travel is possible in the near future, but whether it is possible in principle. And at this stage the answer to that question appears to be yes. □

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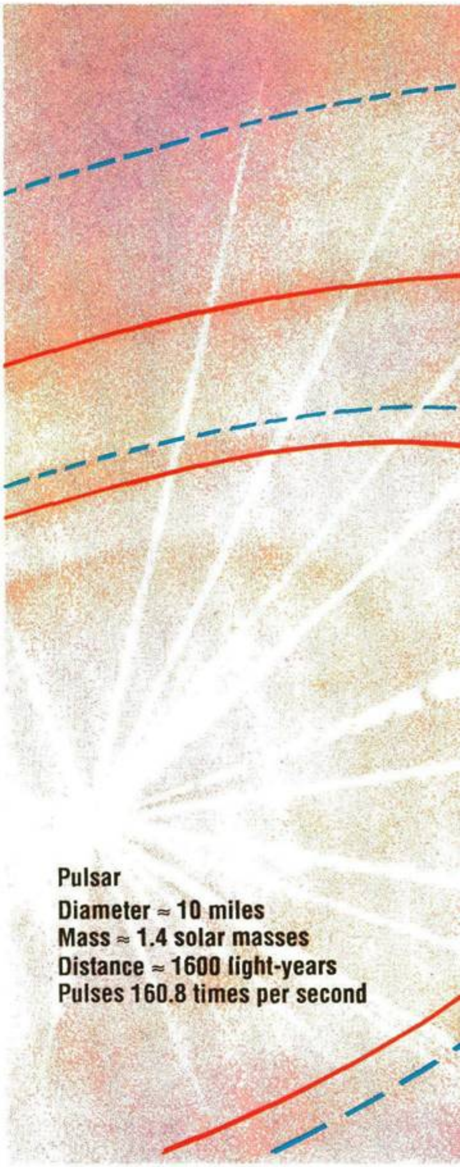
*Barry Parker is a professor of physics and astronomy at Idaho State University. This article is adapted from his book,* Cosmic Time Travel: A Scientific Odyssey *(Plenum Press, 1991).*

# LOST & FOUND: PULSAR PLANETS

Before the astonishing discovery of the first planet seen orbiting another star was retracted, astronomers discovered a second pulsar planet system.

By David Bruning



Last July a group of astronomers announced the discovery of the first extrasolar planetary system (see "The First Planet Beyond the Solar System" in the December issue). Because the planet orbited a pulsar and not an ordinary star, the discovery was even more startling. Then to add to the drama, another research team announced in January their discovery of a second pulsar planetary system.

This team, Aleksander Wolszczan of the Arecibo Observatory and Dale Frail of the National Radio Astronomy Observatory, didn't start out looking for planets around pulsars. They were hunting for millisecond pulsars, neutron stars that emit radio pulses hundreds of times each second. Few millisecond pulsars are known, so the astronomers used the 305-meter radio telescope in Arecibo, Puerto Rico, to search for more of these objects.

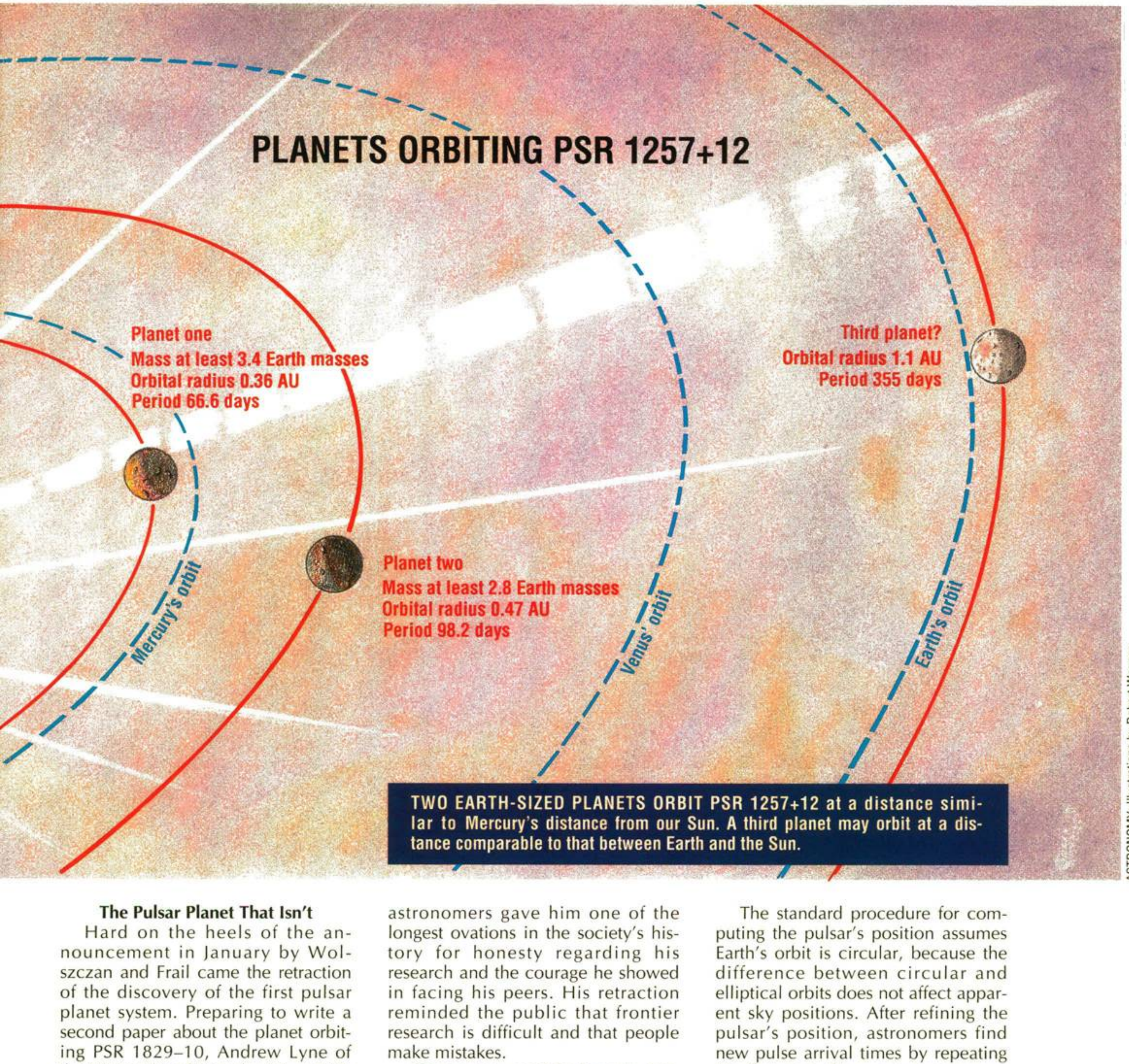
The effort, which started in February 1990, turned up two new millisecond pulsars, PSR 1257+12 and PSR 1534+12, both of which are different than other known millisecond pulsars. PSR 1534+12 is in a short-period binary system that apparently evolved from two massive stars. Study of the strong gravitational forces acting on this pulsar already has helped scientists test Einstein's theory of relativity.

But for most people, the more exciting of the two pulsars is 1257+12. Wolszczan and Frail found that the radio pulses from this star sometimes appear up to 15 trillionths of a second earlier or later than expected. Pulsars emit radio pulses so precisely that astronomers can measure their periods to a small fraction of a trillionth of a second. Pulses that arrive even one-trillionth of a second early or late are a clear signal that something is different about the pulsar.

After carefully evaluating the pulse arrival times from 1257+12, Wolszczan and Frail thought they may have discovered a planetary system. To assure that the variations were not due to their equipment, they also observed the pulsar with the Very Large Array near Socorro, New Mexico, and found the same discrepancies in the pulse arrival times.

Two or three components contribute to the observed variations in pulse arrival times, one with a period of 66.6 days, a second with a period of 98.2 days, and a possible third, with a year-long period. The simplest and most likely explanation for the variations is that two or three companions to the pulsar pull on the star as they orbit about it. We often think of Earth orbiting the Sun as if the Sun were fixed in space, but in fact Earth's gravity also makes the Sun orbit about a point astronomers call the center of mass, or barycenter. Likewise, the pulsar's companions force the star to orbit about a barycenter. The variations in the pulse arrival times indicate that the pulsar moves around an orbit roughly 900 kilometers in radius with a speed of 0.7 meter per second.

From their orbital periods, the astronomers determined the distances of the companions, 0.36 and 0.47 astronomical units (AU). (One AU is the distance between the Sun and Earth.) Not knowing the pulsar's mass, they assumed that it is like other pulsars and has 1.4 solar masses. The mass of each companion could then be found by comparing the orbital radius of the pulsar with that of the companion. Finding the companion's mass this way is like putting two children of different weights on a seesaw and moving them back and forth along the board until they exactly balance. Wolszczan and Frail found that the inner planet's mass is at least 3.4 times the Earth's and that the outer planet has at least 2.8 Earth masses. Their measurements are sensitive enough to detect objects with a mass about one-sixth that of Earth.



TWO EARTH-SIZED PLANETS ORBIT PSR 1257+12 at a distance similar to Mercury's distance from our Sun. A third planet may orbit at a distance comparable to that between Earth and the Sun.

ASTRONOMY: Illustrations by Robert Wegner

### The Pulsar Planet That Isn't

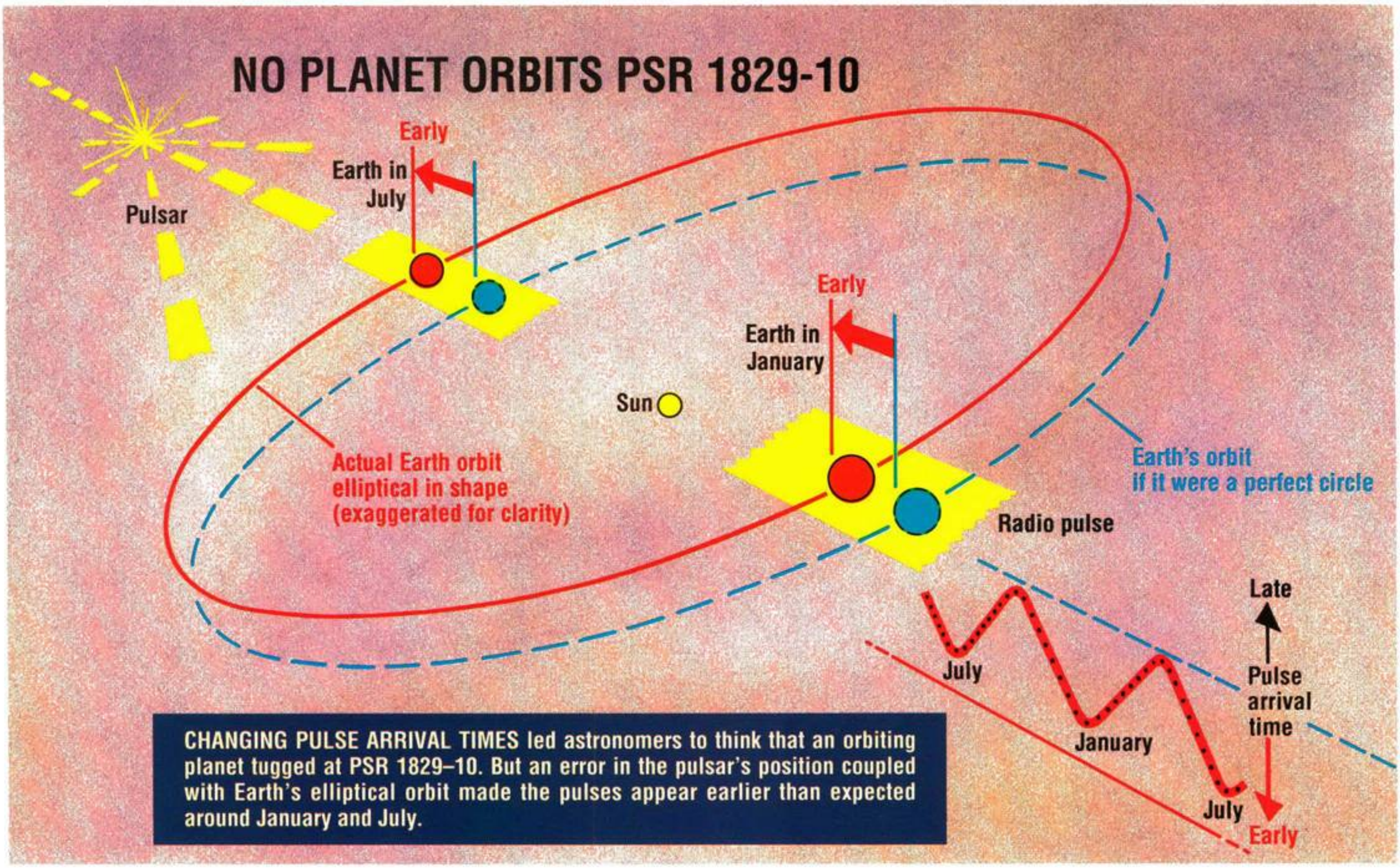
Hard on the heels of the announcement in January by Wolszczan and Frail came the retraction of the discovery of the first pulsar planet system. Preparing to write a second paper about the planet orbiting PSR 1829–10, Andrew Lyne of the University of Manchester and his colleagues attempted to refine the planet's orbit. They added data obtained during the last half of 1991 to their existing data and reanalyzed the entire series of pulse arrival times. While double-checking the analysis procedure, the astronomers discovered an error in the way they corrected for the shape of Earth's orbit. Lyne immediately realized that the pulsar's companion was fictitious.

Proclaiming his "embarrassment was unbounded," Lyne nonetheless disclosed his error to the scientific community and retracted the discovery at the January meeting of the American Astronomical Society. Instead of criticizing Lyne, the astronomers gave him one of the longest ovations in the society's history for honesty regarding his research and the courage he showed in facing his peers. His retraction reminded the public that frontier research is difficult and that people make mistakes.

The process used by Lyne to analyze pulse arrival times consisted of two basic steps. Arrival times depend precisely on where Earth is in its orbit and where the pulsar appears in the sky. The first step corrected the pulse arrival time for the motion of Earth about the Sun, because Earth's shifting position can make pulses appear to arrive up to 8 1/2 minutes early or late. The astronomers' analysis accurately corrected the pulse arrival times for Earth's motion about an elliptical orbit. However, small errors remained in the corrected arrival times because the pulsar's position wasn't precisely known. So the second step of the analysis refined the pulsar's position.

The standard procedure for computing the pulsar's position assumes Earth's orbit is circular, because the difference between circular and elliptical orbits does not affect apparent sky positions. After refining the pulsar's position, astronomers find new pulse arrival times by repeating the first step. They repeat steps one and two until they obtain the desired accuracy in the pulsar's position.

Most pulsars have reasonably precise initial positions so there is normally little correction to their positions. But Lyne and his colleagues needed to apply a large correction to 1829–10's position — 7 arcminutes. Unfortunately, the analysis procedure did not communicate the corrected position to the repeated first step. Instead, the repeated first step used the initial position, resulting in improperly corrected pulsar arrival times. Effectively, a small component of the elliptical character of Earth's orbit remained in the pulse arrival times owing to the uncorrected position.


NO PLANET ORBITS PSR 1829-10
Pulsar
Early
Earth in July
Early
Earth in January
Sun
Actual Earth orbit elliptical in shape (exaggerated for clarity)
Earth's orbit if it were a perfect circle
Radio pulse
Late
Pulse arrival time
July
January
July
Early

**CHANGING PULSE ARRIVAL TIMES** led astronomers to think that an orbiting planet tugged at PSR 1829–10. But an error in the pulsar's position coupled with Earth's elliptical orbit made the pulses appear earlier than expected around January and July.

The result was that sometimes the pulses appeared to come 5 milliseconds early or late compared to the constant arrival time expected for the radio pulses (see illustration above). In July Earth was closer to the pulsar (which appears in Scutum) than the circular orbit assumed in the second step of the analysis, so the pulses appeared to come early. In October, the two orbits have the same radius, so the pulses arrive on time. But in January, the pulses again appear to arrive early owing to the differences between the true orbit and the assumed circular orbit.

Not knowing what the arrival time should be, the researchers reasonably assumed that the changing arrival time represented a variation about an average value. This made the pulses appear to come sometimes early and sometimes late, mimicking the behavior of a pulsar being pulled by an orbiting planet. In retrospect, we see that the astronomers were seeing the pulses arrive early twice a year because of the differences between the actual and assumed orbits.

So there is no planet orbiting 1829–10. But that isn't as important as the impact the short-lived discovery had on astronomy. Astronomers were forced to consider the existence of planets about stars other than those like the Sun.

### How to Make a Pulsar Planet

Prior to the discovery of pulsar planets, astronomers thought that burned-out stellar remnants like PSR 1257+12 couldn't have planets because the supernova explosion that created the neutron star would either destroy the planets or fling them out of orbit around the star. But that assumed the planets were created at the same time as the star. Astronomers now think pulsar planets probably form after the supernova explosion.

A millisecond pulsar starts as a binary system with a massive star and a less massive star. The massive star burns up the hydrogen in its core quickly. Depleting its other energy reserves causes the star to contract, which triggers the supernova explosion. The remaining bit of the star's core contracts until the protons and electrons squeeze together to form neutrons. The new neutron star spins several times per second, emitting strong radiation that slowly evaporates its companion star. Gas evaporated from the companion spirals into the neutron star, which causes it to spin faster. As the companion is slowly destroyed, the neutron star spins faster and faster, eventually spinning several hundred times per second.

Recent calculations by Marco Tavani of the University of California, Berkeley, and his colleagues indicate that some of the material from the companion star moves away from the neutron star to form a disk several astronomical units in diameter. Because 1257+12 is about one billion years old, enough time has elapsed for planets to form from its disk. Some astronomers call these "second-generation planets" to differentiate them from planetary systems like ours that formed simultaneously with the star.

The discovery of planets orbiting PSR 1257+12 was purely accidental, but it remains the first planetary system found around another star. It will take several more years of observations to verify that the planets really exist and to settle the question about the presence of a possible third planet. Other pulsars may have planetary systems, so astronomers are going to go back and look at their data to see if they may have overlooked any other systems. And theorists will be busy trying to understand what the 3-to-2 ratio of the planets' periods implies about their formation.

However, one nagging problem remains. If astronomers' ideas about star formation are correct, many first-generation planets should orbit stars like the Sun. Although astronomers have yet to discover such a system, they continue their search, hoping to duplicate the discovery of PSR 1257+12. □

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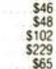

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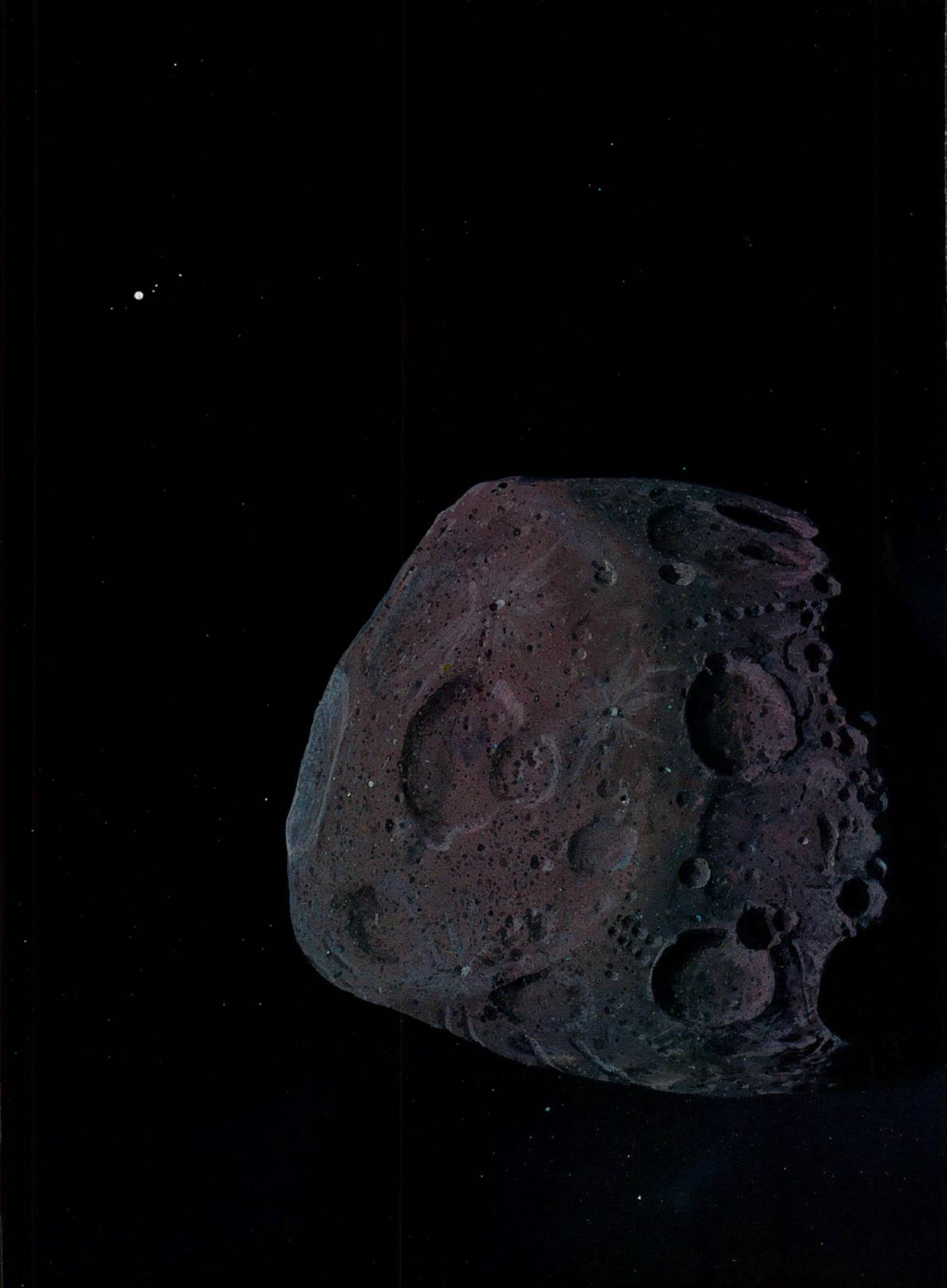


# The CAPTIVE Asteroids

Locked by gravity into the same orbit as a planet, Trojan asteroids may be examples of objects that built the planets billions of years ago.

by Clifford J. Cunningham

Illustration by William Hartmann

As the giant 200-inch Hale telescope began probing the depths of the universe, a more prosaic observing program was swinging into action a short distance away. At the 18-inch Schmidt camera, Henry Holt and David Levy were busily preparing circular films to photograph a swath of the sky in search of asteroids. The night was June 22, 1990. They were about to make a discovery that would change our understanding of the solar system.

The targets of their photographic search were elusive near-Earth asteroids, objects that cross Earth's orbit and move so quickly that astronomers suspect many come and go without ever being noticed.

But many of the search team's photographs routinely reveal other asteroids. Some orbit in the main asteroid belt between Mars and Jupiter. Occasionally, the hunters nab asteroids farther out in space, ones that circle the Sun in the same orbit as Jupiter. These asteroids keep pace with the giant planet and group into two clouds — one ahead of Jupiter and one following it. Together, the two families of objects are called the Trojans. They are asteroids held captive by Jupiter's gravity.

Each asteroid — whether it be main-belt, Earth-crosser, or Jupiter Trojan — has its own characteristic motion on photographic film. The asteroid Holt and Levy found that night had a motion unlike those of any of the three classes of asteroids. Its motion indicated an unusual orbit for an asteroid; it was the same as the orbit of Mars. The first Mars Trojan had been found.

**CAPTURED BY JUPITER'S GRAVITY**, a Trojan asteroid shares Jupiter's orbit. Now known to exist by the hundreds, Trojan asteroids may be the stuff out of which planets formed.

"A few weeks later I was outside with my mother," relates Levy. "We were looking at Mars, noting its beauty. I asked off the cuff if she knew how many objects share that orbit. She said three, Mars and its two moons. I said four — now there's a Mars Trojan. For a planet that we know so well, that gave me a neat feeling."

### Eureka!

The 1990 discovery of a Mars Trojan was so startling that the world's foremost asteroid experts could scarcely believe it. For Brian Marsden, director of the Minor Planet Center in Cambridge, Massachusetts, the discovery of the Mars Trojan was "a bit of a shock."

The discovery came as part of a methodical Mars- and Earth-crossing asteroid and comet survey being conducted under the direction of Eugene and Carolyn Shoemaker. On that night in June 1990, Holt and Levy exposed about 30 films, each for 8 minutes. The following day Levy noticed a faint object, about 17th magnitude, on a pair of films. This sparked his interest, as it appeared to be moving faster and at a different angle than asteroids normally move.

They photographed it again that night, confident in having found a new asteroid. The first to recognize it as a Mars Trojan was Edward Bowell of Lowell Observatory. "It hit me right away," said Bowell, "but Brian Marsden, being a cautious soul, wouldn't believe me." The asteroid was given the provisional designation 1990 MB, and although it will not receive a permanent number or name until it is observed again this year, it has been informally dubbed Eureka.

### Tip of the Iceberg

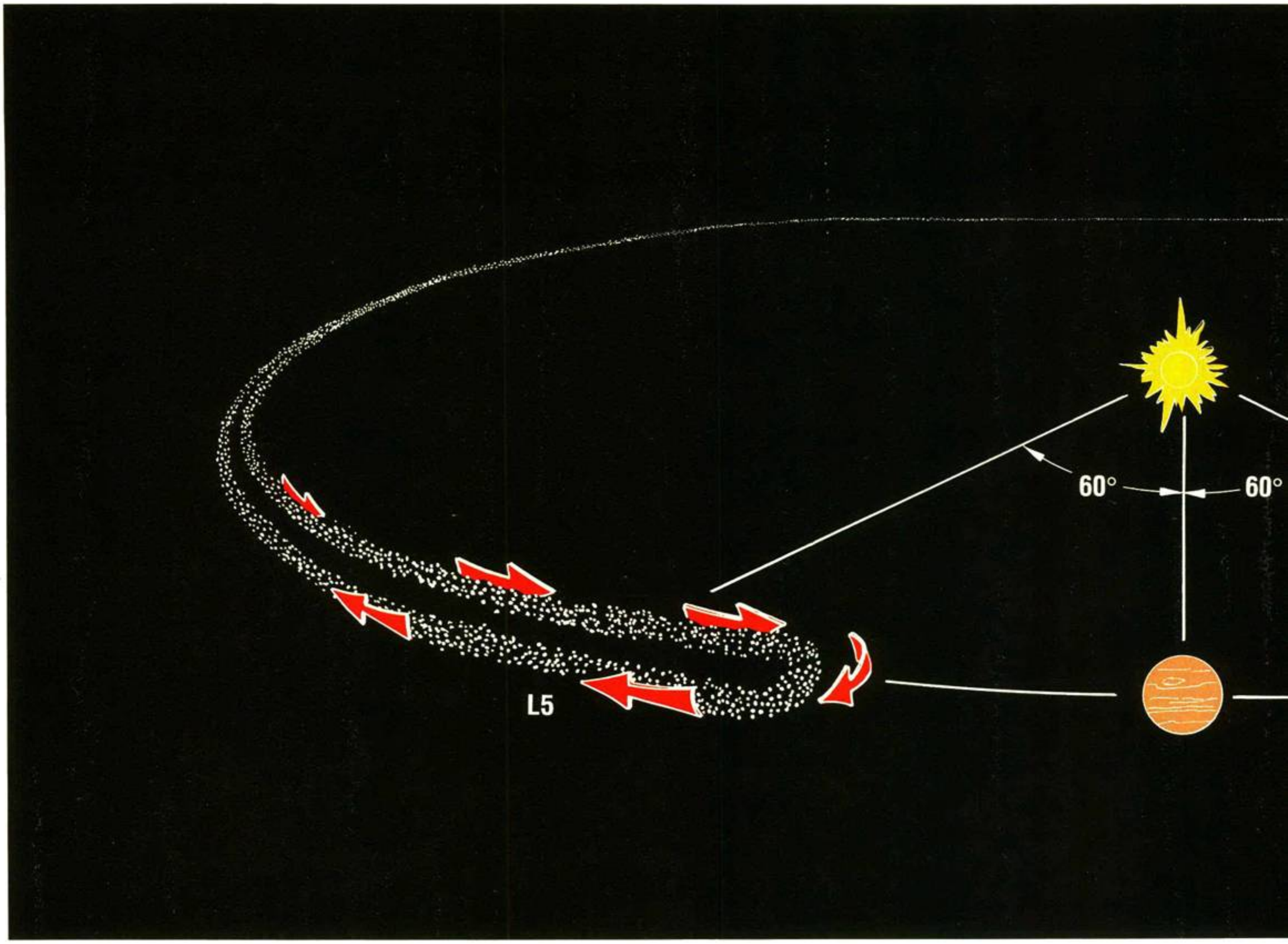
The discovery of the Mars Trojan prompted astronomers to re-examine what we know about Trojan asteroids. Astronomers discovered the first member of this exclusive family in 1906. The new asteroid shared Jupiter's orbit and was given the name Achilles. A few months later, astronomers found a second asteroid traveling along with Jupiter. This one received the name Patroclus. (The men after whom the asteroids were named were heroes of the Trojan War of about 1400 B.C. between Troy and the Greek states.) With the precedent set, astronomers adopted the custom of referring to asteroids in Jupiter's orbit as Trojans and naming all Jupiter Trojans after other heroes of the legendary battle for Troy.

Credit for much of our knowledge about Jupiter's Trojans goes to Eugene Shoemaker. He began a systematic search for Trojans with Palomar's 18-inch Schmidt in 1985 and renewed the search in 1988. So far, he and his search team have bagged 45 Trojans. Altogether, astronomers have identified 300 Trojans.

But that is only the tip of the Trojan iceberg. Shoemaker estimates there are 2,300 Trojans bigger than 15 kilometers in diameter. To put that figure in perspective, it is nearly half the currently numbered population of the main asteroid belt between Mars and Jupiter.

### Wandering Heroes

Trojan asteroids cluster about two points in the orbit of a planet called Lagrangian points (for the



18th-century French mathematician Joseph Louis Lagrange who first worked out their significance). One of the Lagrangian points, called L4, sits 60° ahead of a planet. The other, L5, sits 60° behind the planet. Objects at these points become trapped by the combined gravitational tugs of the nearby planet and the Sun.

Trojans circle the Sun in stable but unusual orbits. A Trojan doesn't stay at either the L4 or L5 point but instead oscillates around it, moving back and forth along the planet's orbit. Trojans follow a teardrop-shaped path that in the case of Jupiter's Trojans extends for about 40° along the Jovian orbit. Trojans can be found anywhere along this zone and, in fact, are rarely found at the L4 or L5 points themselves.

Calculations suggest Trojans can wander even farther afield. There may be Trojans in enormous horseshoe-shaped orbits that extend up to 300° away from Jupiter, allowing Trojans associated with one Lagrangian point to move most of the way around the Sun to the other L point.

When the Mars Trojan was found, theoreticians scrambled for answers. What type of orbit was it in? How long had it been there? And why didn't we find it sooner?

Kim Innanen of Canada's York University, an expert on orbital dynamics, has some of the answers. Innanen suggests the Mars Trojan was not found sooner because calculations of where to look predicted a faint object far away from the Lagrangian point, making attempts to pin down its location very difficult. As Innanen puts it, "A back-of-the-envelope calculation discourages anyone from searching, which only goes to prove that one should not be discouraged by learned celestial mechanicians who have not looked!"

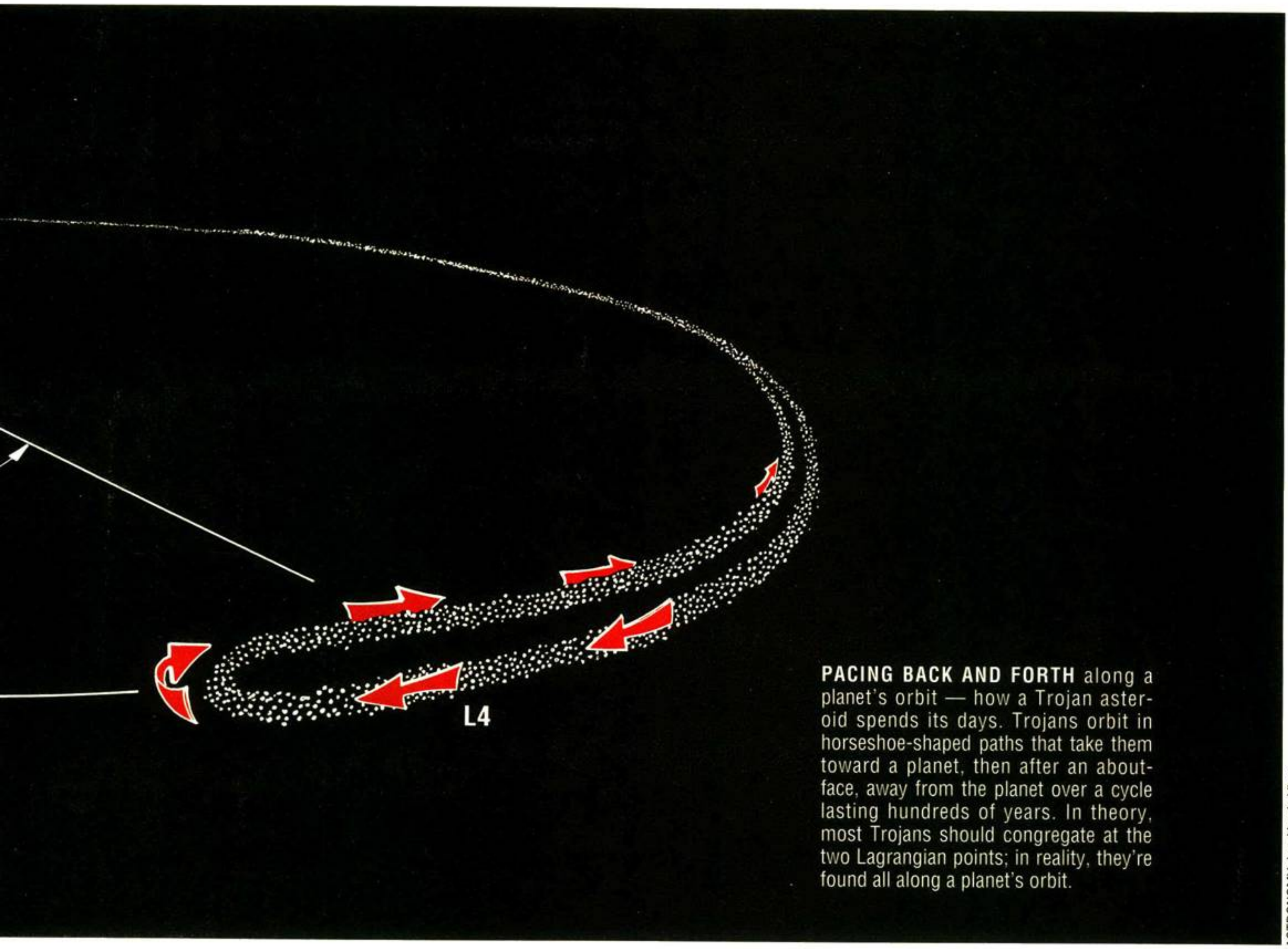
Like the Jupiter Trojans, the Mars Trojan does not stay the same distance from its captor planet. It cycles along a very long horseshoe, covering 80° along the Martian orbit, a distance so long that the little asteroid takes 1,000 years to make a complete circuit. It is as if Eureka is on a leash — Mars lets its pet Trojan stray only so far before bringing it home, closer to the L5 point.

"A central question," says Innanen, "is how long the Mars Trojan has been there." Astronomers can use computers to simulate the evolution of orbits. But as Innanen explains, "Calculations longer than a few million years for the inner solar system are painful — it brings computers to their knees. We're just going to have to wait for the next generation of computers."

What we are sure of is that the Mars Trojan is about 3 kilometers in diameter and in a very stable orbit. However, Shoemaker believes the asteroid is too small to have survived in its present state from the origin of the solar system some 4.5 billion years ago. "I believe it was captured at some time rather recently, that is, within the last 500 million years."

### Unseen Companions

The discovery of an asteroid in the orbit of Mars prompts the question of how many other planets have retinues of Trojans. One school of thought says that the stable regions in



**PACING BACK AND FORTH** along a planet's orbit — how a Trojan asteroid spends its days. Trojans orbit in horseshoe-shaped paths that take them toward a planet, then after an about-face, away from the planet over a cycle lasting hundreds of years. In theory, most Trojans should congregate at the two Lagrangian points; in reality, they're found all along a planet's orbit.

ASTRONOMY: Lee Vande Visse

the orbits of the outer planets Saturn, Uranus, and Neptune are so small that the chance of any objects' existing in those areas is very slight.

But Innanen is not so sure. "In terms of our understanding, it is still the early days for Uranus and Neptune. They certainly have stable regions at the Lagrangian points. Our simulations also suggest it is well worth searching for Saturn Trojans in horseshoe orbits." The problem with finding Saturn Trojans is that they will be faint and the gravitational effects of Jupiter make it difficult to predict where they are in the sky.

But other Trojans could exist closer to home. As Marsden concedes, "If Mars has some, Earth is quite likely to have them, too. Quite a lot of objects come into Earth's proximity."

People have long speculated about the existence of Earth Trojans. Clyde Tombaugh, the discoverer of Pluto, conducted a search for small natural Earth satellites in the 1950s. Scott Dunbar did a photographic search with the 48-inch Schmidt from 1978 to '82, and in 1981 and '82 Francisco Valdes and Robert Freitas used the 24-inch Burrell Schmidt on Kitt Peak in Arizona to look for objects near Earth's Lagrangian points. None were seen. Eleanor Helin, who found a prediscovery image of the Mars Trojan on a photograph she took in 1979, believes that establishing the existence of Earth Trojans "would be a very significant discovery. It would be far more important than other asteroid discoveries, because it relates to our planet. Such objects may have been held there over the eons. It would be quite a revelation."

### Seeking the Holy Grail

Much of the current interest in Trojan asteroids comes because these objects could tell us a great deal about the origin and development of the solar system. Were they objects that simply wandered into the spider's web of gravity spun by the planets, or did they form in these unique orbits, locked in an eternal embrace with their bigger siblings? Determining what the Trojans are made of could tell us the answers.

The first step in determining an asteroid's composition is figuring out how reflective it is. Many of the known Trojans are good-sized objects, typically 100 km across. But most of these appear faint from Earth, usually dimmer than magnitude 15. This suggests they are dark. They reflect only 5 percent of the sunlight that hits them, making them dark as charcoal, a characteristic shared by other objects in the outer solar system: the rings of Uranus, the small moons of Uranus and Neptune, part of the surface of Saturn's moon Iapetus, and inactive comets (ones not currently ejecting gas and dust).

The dark nature of the Trojans is one reason Shoemaker has proposed that the Trojans aren't rocky asteroids at all. Virtually all of them, he suggests, are made of the same stuff as comets. "Trojans are identical in origin with Oort cloud comets. They represent planetesimals, the building blocks of the outer planets."

Shoemaker estimates that the present population of Trojans came from a much larger collection of

NASA/JPL

**REPEATED COLLISIONS SMOOTH** the surfaces of main-belt asteroids orbiting between Mars and Jupiter (such as Gaspra, shown here). Trojan asteroids, thought to be less eroded by impacts, may be pristine examples of the objects that coalesced to form the planets.

planetesimals, as much as 60 Earth-masses' worth, that formed 4.6 billion years ago in the region between present-day Jupiter and Saturn. Today, Jupiter orbits 5.2 astronomical units from the Sun and Saturn orbits at a distance of 9.5 AU. (1 AU is the average distance from Earth to the Sun.) But in the early days of planet formation, the proto-Jupiter may have started out as far as 8 AU from the Sun. It swept up material from a zone that extended inward to 5 AU and outward to 9 AU. About 10 Earth masses of this early material came together to form the rocky core of Jupiter. The gravity of the proto-Jupiter flung most of the other planetesimals under its control out of the solar system. But Jupiter's gravity captured a small percentage and, after subjecting them to a series of close encounters with Jupiter, trapped these planetesimals at the L4 and L5 points.

"The Trojans," enthuses Shoemaker, "are wonderful dynamical curiosities. If we can determine the efficiency of the process that captured the Trojans, we can work back in time to what the planetesimal swarm was to begin with. It is a search for where the planets came from. That is the Holy Grail."

Astronomers are particularly inspired by the prospect that Trojans may be pristine remnants of the early solar system. Once locked into their orbits, oscillating about the Lagrangian points, Trojans would have been exposed to fewer collisions than their counterparts in the main asteroid belt between Mars and Jupiter. The few collisions between Trojans that did occur would have happened at relatively slow speeds, so slow that colliding Trojans might not have shattered but instead stuck together. Astronomers William Hartmann and Dale Cruikshank think they have found just such a strange asteroid. Called 624 Hektor, it is the largest of the Jupiter Trojans. Observations of its fluctuating brightness point to an asteroid that is dumbbell-shaped and rotating every 6.9 hours. It may, in fact, be the product of two asteroids' hitting and fusing.

While surface-wrenching collisions have pelted main-belt asteroids, and eruptions of gas and dust have reshaped active comets, the surfaces of the Trojans have likely gone unchanged for billions of years. The lack of shattering collisions in the haven of the Lagrangian points means that Trojan asteroids, whether tied to Jupiter, Mars, or another planet, may be one of the few fossils we can find from the days before the planets formed. A close look at a Trojan asteroid might indeed be a glimpse of the Holy Grail of the solar system. ☐

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*Clifford J. Cunningham has been engaged in photometric studies of asteroids since 1980. He is author of the 1988 book* Introduction to Asteroids *published by Willmann-Bell, Inc.*

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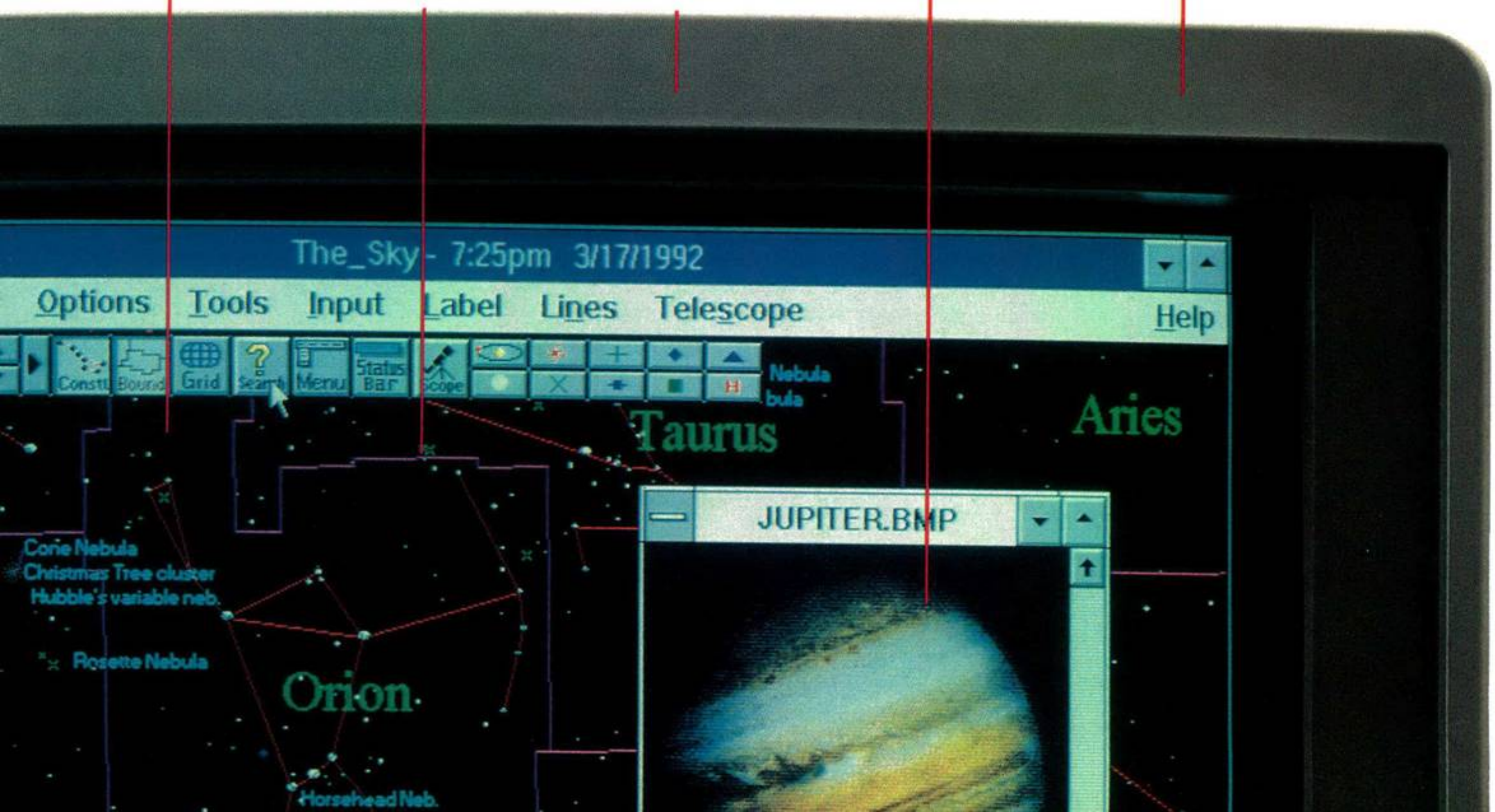
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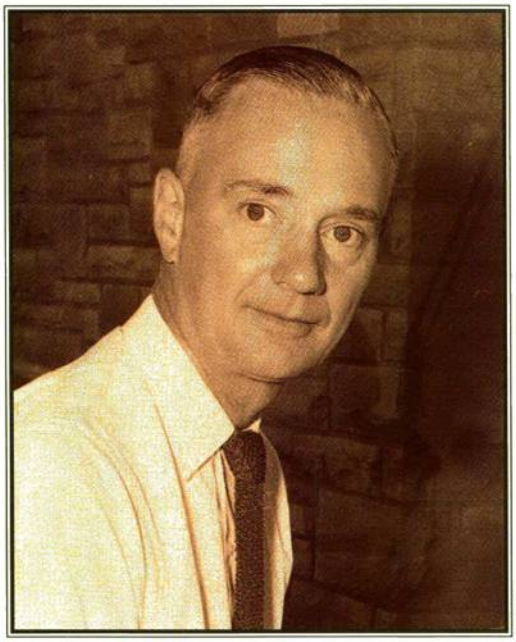
# The Birth of *Radio Astronomy*

A home experimenter turned Karl Jansky's discovery of radio emission from the Milky Way Galaxy into the fledgling science of radio astronomy.

By Robert Wearner

The names of most astronomers are quickly forgotten, as are their fleeting discoveries. Only a few make lasting contributions to astronomy. Among these stand giants like Johannes Kepler, William Herschel, and Edwin Hubble. Some of the giants, such as George Ellery Hale, have left a legacy of large optical telescopes and observatories. One astronomer, Grote Reber, is largely forgotten today, but he made a lasting contribution by designing the modern radio telescope.

Reber designed and built the first parabolic-dish radio telescope. Most modern radio telescopes use one or more of these dishes to detect radio emission from celestial objects. But the idea to use a dish-type radio antenna to study stars and our Galaxy's radio sources wasn't new to Reber. Karl Jansky (1905-1950), the engineer who opened the radio window to the universe, first suggested it.


NRAO

**GROTE REBER** developed the dish-type radio telescope and mapped our Milky Way Galaxy in 1937 using the radio window opened by Karl Jansky.

After obtaining his college degree in physics and completing a year of post-graduate study, Jansky joined the Bell Telephone Labs near Cliffwood, New Jersey, in the summer of 1928. His supervisor assigned him the task of finding the cause of the static that interfered with shortwave transatlantic radiotelephone service. Customers paid $75 for a three-minute call and they did not like the hissing noise.

Late in 1929, Jansky started to build a rotating antenna in fields that once grew corn and potatoes. The 96-foot-long antenna was 13 feet high and used almost 400 feet of brass pipe mounted on a wooden frame. The antenna, which was hoisted on four Model T Ford wheels, turned three times per hour around a 33-foot-diameter circle, causing Jansky's co-workers to call it "Jan's merry-go-round." Rotating the antenna enabled Jansky to determine the direction to the radio source that was causing the radiotelephone interference. This large antenna operated at a wavelength of 14.6 meters.

In 1930, the lab and Jansky's antenna moved to Holmdel, New Jersey. Later in that year, Jansky observed only a little static, so he decided to investigate other aspects of radio communications. Resuming his search for the source of static in August 1931, Jansky plotted the directions from which the noise appeared to emanate. By 1932, he had identified three components to the radio noise: local thunderstorms, distant thunderstorms, and a hiss.

By comparing records of succeeding days, he found that the source of the hiss did not recur in exactly 24 hours but in 23 hours and 56 minutes. In a year's time, the pattern had slipped one whole day. Not being an astronomer, Jansky took some time to realize that he was dealing with a source fixed in space. He ruled out the Sun as the source of the noise, because the signal recurred four minutes earlier each day. (Jansky could have detected radio bursts from the Sun, but it was in a quiet state near sunspot minimum in the early 1930s.) Further observations revealed to Jansky that the signals picked up by his antenna came from the direction of the constellation Sagittarius, the center of the Milky Way Galaxy.

Jansky reported his findings in the December 1932 and October 1933 issues of the *Proceedings of the Institute of Radio Engineers.* On April 27, 1933, he presented a paper titled "Electrical Disturbances of Extraterrestrial Origin" to a small audience in Washington, D.C. His paper attracted little attention from the scientific community, much to Jansky's disappointment. But it did get him some national media exposure. A *New York Times* story reported Jansky's discovery in the May 14, 1933, Sunday edition. On May 15, the NBC Blue Network radio broadcast carried Jansky's hiss by way of a direct hookup to the radio telescope.

Jansky once again tried to interest the scientific community in his discovery of an astronomical radio source in a paper presented in Detroit on July 3, 1935. This paper described his detection of radio noise all along the plane of the Galaxy. But there were only two dozen people in his audience. Several reasons explain the lack of response on the part of astronomers to Jansky's momentous discovery. Astronomers were not yet ready to venture into the radio portion of the spectrum, having just started photographic studies of stars and galaxies with large telescopes after years of visual work. Also, radio technology was not a part of the astronomers' repertoire, so they didn't know how to judge Jansky's results properly. It wasn't clear that radio emission studies would greatly aid studies of the Galaxy. And the country was deep in the Great Depression, so university astronomy departments couldn't afford to hire radio engineers to pursue this discovery.

Jansky proposed building a dish-type radio telescope to further pursue his cosmic radio source. But the beginning of radio astronomy came to a brief end when Jansky's supervisor asked him to investigate another aspect of radiotelephone static. Only a few astronomers and radio engineers followed up on Jansky's work. The most successful was Grote Reber.

### The First Radio Dish

Grote Reber — born December 22, 1911, in Wheaton, Illinois — started in radio communication as an enthusiastic radio "ham." But after contacting other radio amateurs in over 60 countries, he was ready for a new challenge. While a student at what is now the Illinois Institute of Technology, Reber thought about using his radio transmitter to bounce signals off the Moon. However, his calculations showed that the signals would be too weak to receive. After graduation he went to work at the Stewart-Warner Company, designing radio receivers.

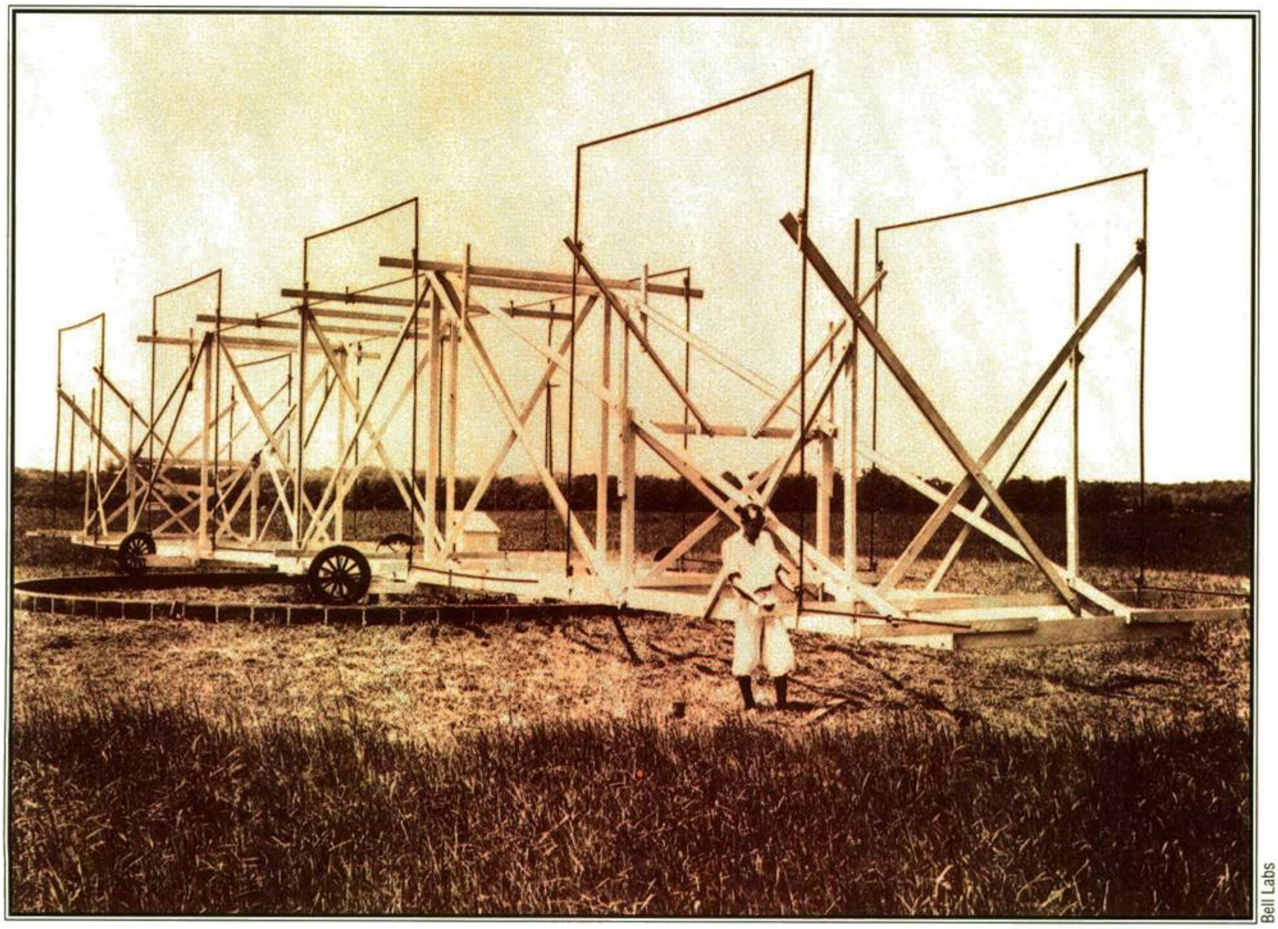
Reading Jansky's articles inspired Reber to try as a home experiment to listen to the signals emitted by our Galaxy. Such a project was beyond the range of normal amateur radios. He needed special equipment. To capture the longer radio waves emitted by celestial bodies, Reber laid plans to make a parabolic reflector or dish antenna. The reflector would collect radio waves just as the mirror in an optical reflecting telescope collects light waves. Reber's reflector then would focus the radio waves on a small antenna, which in turn would feed a radio receiver.

After drawing up plans for a dish antenna, the young engineer asked for a bid from the American Bridge Company. Their price of $7,000 seemed excessive to a young man just starting a career in the midst of the Great Depression, so Reber decided to build the dish himself.

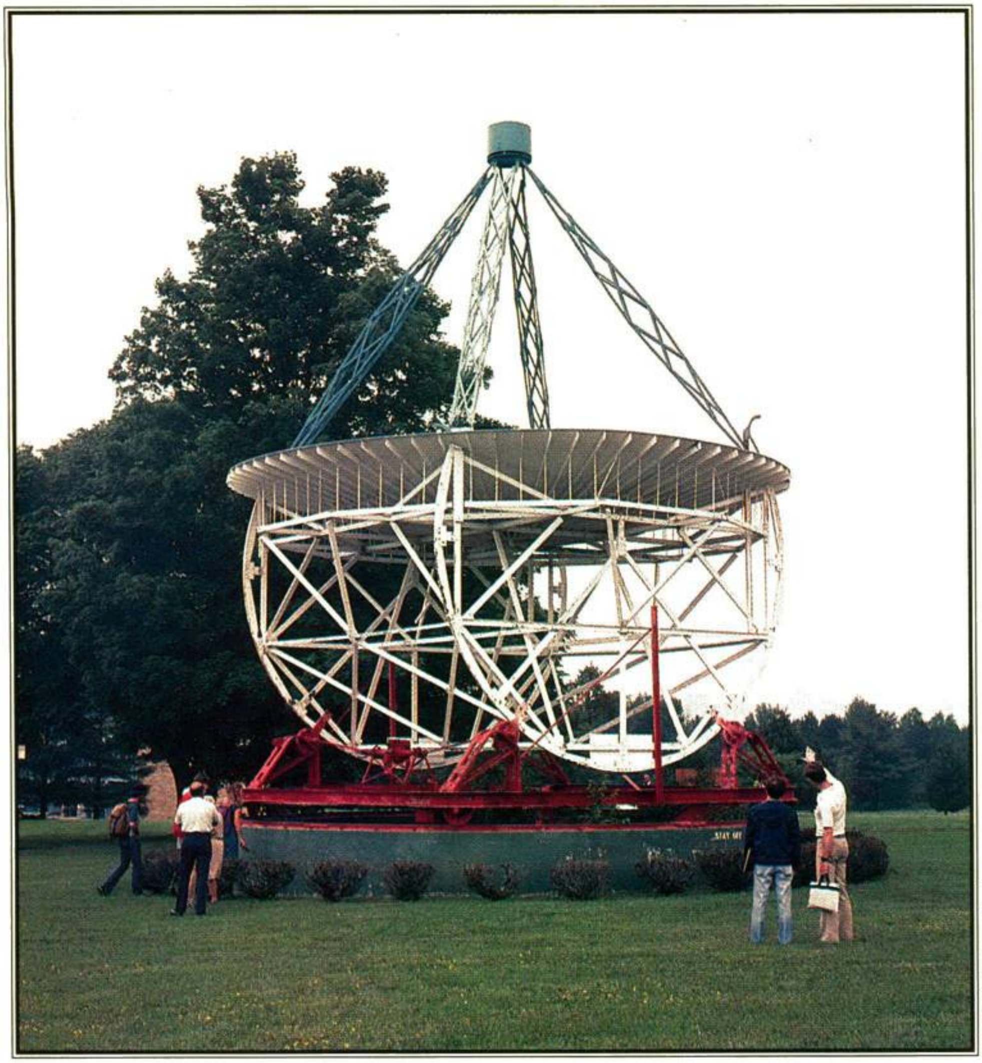
With the assistance of two men, he erected a strange-looking structure in his yard at 212 West Seminary Street in Wheaton. The mirror had a diameter of 31 feet and a focal length of 20 feet. The reflector was made of 45 pieces of galvanized sheet metal screwed to 72 radial wooden rafters cut to a parabolic shape. The telescope moved only in a north-south direction, a configuration astronomers call a transit instrument.

Reber's neighbors had plenty to talk about as his radio telescope took shape. When it rained, the reflector

**KARL JANSKY'S RADIO ANTENNA** found the cause of static that interfered with radiotelephone service — radio emissions from our Milky Way Galaxy.



Bell Labs



ASTRONOMY: Dave Bruning

NRAO

**REBER'S DISH DESIGN** is copied in many modern radio telescopes, such as the 140-foot telescope at NRAO in Green Bank, West Virginia (left). Reber's original dish is located at the entrance to NRAO (above).

collected a large volume of water, which then poured through the center hole. This caused some to speculate that the machine had something to do with controlling the weather. And after an airplane developed engine trouble over the antenna, others thought that it was a military project, designed to disable aircraft.

In September 1937 after four months of hard work, Reber and his helpers completed the radio telescope at a cost of $1,300. Considering that a new automobile could be purchased for less than $1,000 in those days, this was no small investment on Reber's part.

The engineer let his neighbors continue their speculations as he set about to work out the problems involved in recording signals received from space. Because of interference from auto ignitions, he did most of his work from midnight until dawn. He worked all day at his job with Stewart-Warner, went to bed early, and slept until midnight, when his observations began. Reber obtained vacuum tubes from the University of Chicago and other radio components from his employer as he refined his receivers. He manually recorded the strength of the radio signals off a meter on the receiver.

His early attempts were fruitless. Reasoning that radio sources should behave like other radiation sources and appear brighter at shorter wavelengths, Reber tried operating his radio telescope at shorter wavelengths than Jansky's 14.6 meters. Starting at a wavelength of 9 centimeters (microwaves) he found nothing. By the summer of 1938, he changed to a wavelength of 33 cm but still had no luck. Finally, at 1.87 m (VHF-high shortwave radio), his efforts paid off in the spring of 1939.

Once Reber's radio telescope became operational, he improved the equipment and set about to make a radio map of the Milky Way Galaxy. His map of the radio intensity of celestial objects was akin to the optical maps of the Galaxy first made by William Herschel in the 18th century.

Reber looked through the radio window to make his map of the Milky Way Galaxy. One of his first observations was that cosmic static was strongest when he focused on the constellation Sagittarius. This confirmed Jansky's report. Other hot spots were centered in Cygnus, Cassiopeia, Canis Major, and Puppis.

Working alone in the field of radio astronomy, Reber recognized his duty to publish his findings. This he began to do in 1940. At first, astronomers didn't know how to judge Reber's results, because they never had seen anything like them. Later, they were too busy with defense-related research to pay much attention to the new science. (The paper did make it to Nazi-occupied Holland, however. After reading Reber's article, Jan Oort, the originator of the comet cloud hypothesis, asked Hendrick van de Hulst to study the possibility of radio lines — single wavelengths of emission by a source. Van de Hulst discovered that hydrogen should emit strongly at 21 cm, radiation first observed in 1951.) For nearly a decade Reber's telescope was the only one in the world, and he was the only radio astronomer.

In 1943 Reber turned his radio telescope toward the Sun. He had not done so previously because of his work schedule. Solar radio waves caused his recording instrument to be driven full-scale. Later he learned from articles published after the war that British scientists had accidentally run across solar radio waves in 1942 as they worked on military radar. They thought that the Germans were jamming their equipment when in fact the Sun was the culprit.

Before Reber's Wheaton operations ended in 1947, he worked on improved maps of the Galaxy, detect-

ASTRONOMY: Alan Dyer

**MODERN RADIO TELESCOPES** use many small dishes, like these 85-foot telescopes at the VLA near Socorro, New Mexico, and then add the signals together to study cosmic radio sources.

ing emission from such sources as the Crab Nebula in Taurus and the Rosette Nebula in Monoceros. In 1948 Reber accepted a position as chief of the University of Virginia's experimental microwave radio section and moved his antenna to Sterling, Virginia. While rebuilding the antenna, he installed the turntable he had built in 1941, while considering a move to Texas. This allowed him to move the telescope around in azimuth in addition to the prior up and down motion in altitude, enabling him to look at radio sources anywhere in the sky.

By 1954 Reber joined the Commonwealth Scientific and Industrial Research Organization in Tasmania, off the coast of southern Australia, where he has lived ever since. He left his original radio telescope behind. Eventually it found a permanent resting place in Green Bank, West Virginia, where it stands today near the entrance to the grounds of the National Radio Astronomy Observatory (NRAO). Astronomers today still use the telescope occasionally.

By the 1950s, many other scientists and engineers had joined Reber in radio wave research. Britain, Holland, and Australia led the way and many other nations followed in the construction of giant radio dish antennas. This surge of interest occurred as the many physicists and radio engineers, who were trained during the war in radio communications and radar, now sought new fields of research.

Reber continues his research and even spent several winters in Canada during the 1980s to look for very-long-wavelength radio emissions. But his greatest contributions to astronomy were the introduction of the parabolic reflector radio telescope and the demonstration that the radio window was important to the progress of astronomy. Most modern radio telescopes owe their basic design to the dish Reber built in 1937.

The largest single dish radio telescope is 1,000 feet in diameter and is located at Arecibo, Puerto Rico. Many modern radio telescopes use a combination of small radio dishes to collect radio waves. The antennas are spaced apart and the signals from each are added together. Such a telescope is called a radio interferometer, but it uses the basic radio dish invented by Reber. The largest single grouping of radio telescopes is the Very Large Array (VLA) built outside Socorro, New Mexico. And radio astron-omers can now add signals from radio telescopes on opposite sides of Earth to form an even larger radio telescope with a technique called very long baseline interferometry. The Very Long Baseline Array with 10 antennas spread from New Hampshire to the Virgin Islands and Hawaii is one such telescope. But whether it's one large dish like Arecibo, or the collection of 27 dishes at the VLA, they all owe their existence to the inventiveness of Grote Reber, who launched a life of contributions by building the first dish-type radio telescope. ☐

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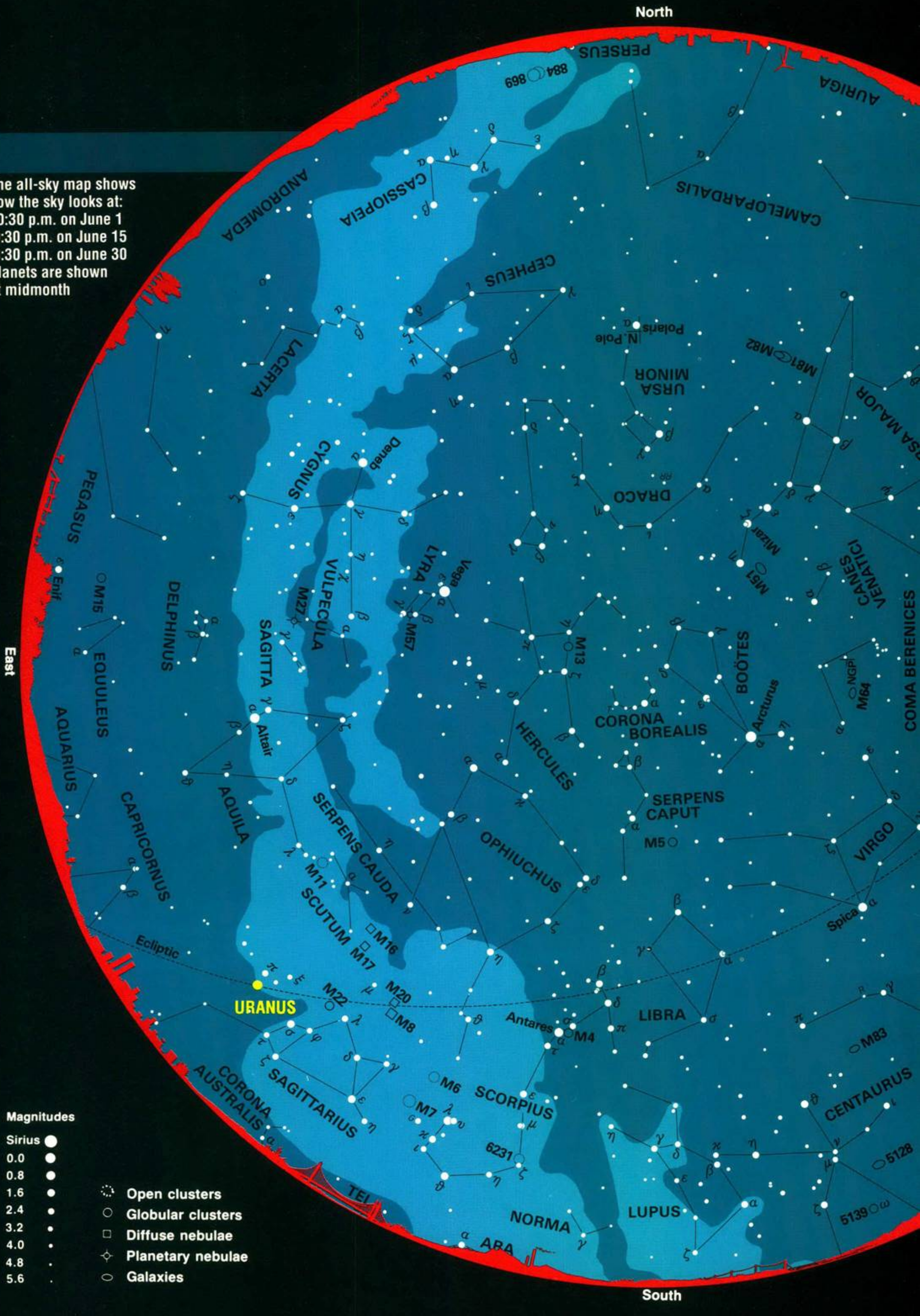
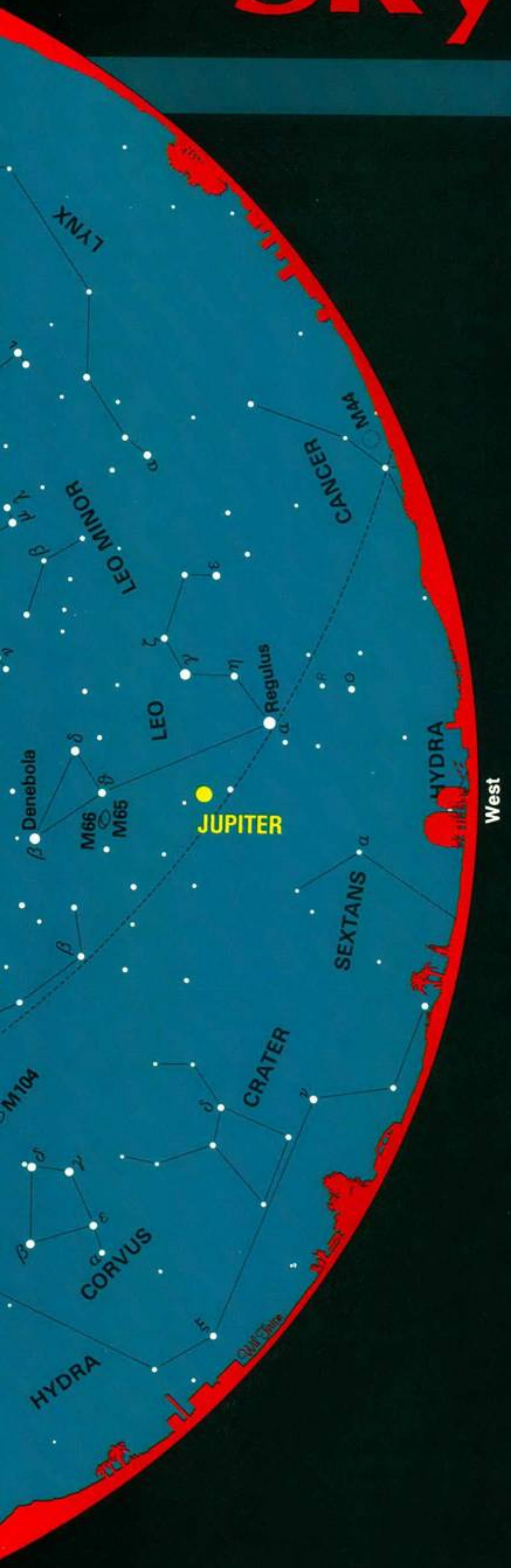
*Robert Wearner is a writer, amateur astronomer, and retired teacher living in Murfreesboro, Tennessee.*

The all-sky map shows how the sky looks at:
10:30 p.m. on June 1
9:30 p.m. on June 15
8:30 p.m. on June 30
Planets are shown at midmonth


North
South
East
PERSEUS
884
869
AURIGA
CASSIOPEIA
CAMELOPARDALIS
ANDROMEDA
CEPHEUS
Polaris
N. Pole
URSA MINOR
M81
M82
URSA MAJOR
LACERTA
CYGNUS
Deneb
DRACO
PEGASUS
Enif
M15
DELPHINUS
EQUULEUS
VULPECULA
M27
LYRA
Vega
M57
SAGITTA
Mizar
M51
CANES VENATICI
COMA BERENICES
NGP
M64
M13
BOÖTES
Arcturus
CORONA BOREALIS
HERCULES
AQUARIUS
Altair
AQUILA
CAPRICORNUS
SERPENS CAUDA
OPHIUCHUS
SERPENS CAPUT
M5
VIRGO
Spica
M11
SCUTUM
M16
M17
Ecliptic
URANUS
M22
M20
M8
Antares
M4
LIBRA
M83
CORONA AUSTRALIS
SAGITTARIUS
M6
SCORPIUS
M7
CENTAURUS
6231
5128
5139
TEL
NORMA
LUPUS
ARA
Magnitudes
Sirius
0.0
0.8
1.6
2.4
3.2
4.0
4.8
5.6
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies

# Sky Almanac

## June 1992



### A PARTIAL LUNAR ECLIPSE

Observers in North America will see the northern two-thirds of the Moon fade into darkness on June 14/15. The year's first lunar eclipse occurs in the evening sky, beginning at 11:27 p.m. EDT June 14 and reaching maximum eclipse at 12:57 a.m. EDT on the 15th. The eclipse ends at 2:27 a.m. EDT, providing skywatchers with three hours to watch Earth's shadow darken the Moon.

### THE SUN SLIPS AWAY

Eclipse number two of June 1992, a total solar eclipse, is visible in the South Atlantic, occurring just after sunrise. The Moon's umbral shadow path begins to cross Earth at 6:59 a.m. EDT on June 30, blazing a trail that begins near Montevideo, Uruguay, and swiftly moves eastward. Mid-eclipse occurs over the mid-Atlantic at 8:10 a.m. EDT. Totality lasts just over 5 minutes at maximum, and a partial eclipse will be visible across southern Africa and South America.

### THE MOON HIDES NEPTUNE

If you've never seen Neptune, a good chance occurs on the evening of June 16/17 when the nearly full Moon occults the distant planet (while Uranus lies just 2° away). Watch from the eastern U.S. with binoculars or a telescope as the 8th-magnitude "star" is blocked by the onrushing bright limb of the Moon.

## Calendar of Events

**3** The Moon is at perigee (227,005 miles from Earth), 10 p.m. EDT

**7** The Moon passes 7° south of Jupiter, 3 a.m. EDT

First Quarter Moon is at 4:47 p.m. EDT

**13** Venus is in superior conjunction, noon EDT

**15** Full Moon is at 12:50 a.m. EDT; partial lunar eclipse

**16** The Moon passes 1.9° north of Uranus, 9 p.m. EDT

**17** The Moon passes 0.9° north of Neptune, midnight EDT; occultation visible

**18** Asteroid Pallas is at opposition, 7 p.m. EDT

**19** The Moon passes 5° north of Saturn, 3 p.m. EDT

The Moon is at apogee (251,736 miles from Earth), 6 p.m. EDT

**20** Summer solstice is at 11:14 p.m. EDT

**22** Mercury passes 5° south of Pollux, 10 p.m. EDT

**23** Last Quarter Moon is at 4:11 a.m. EDT

**26** The Moon passes 6° north of Mars, 4 a.m. EDT

**30** New Moon is at 8:18 a.m. EDT; total solar eclipse

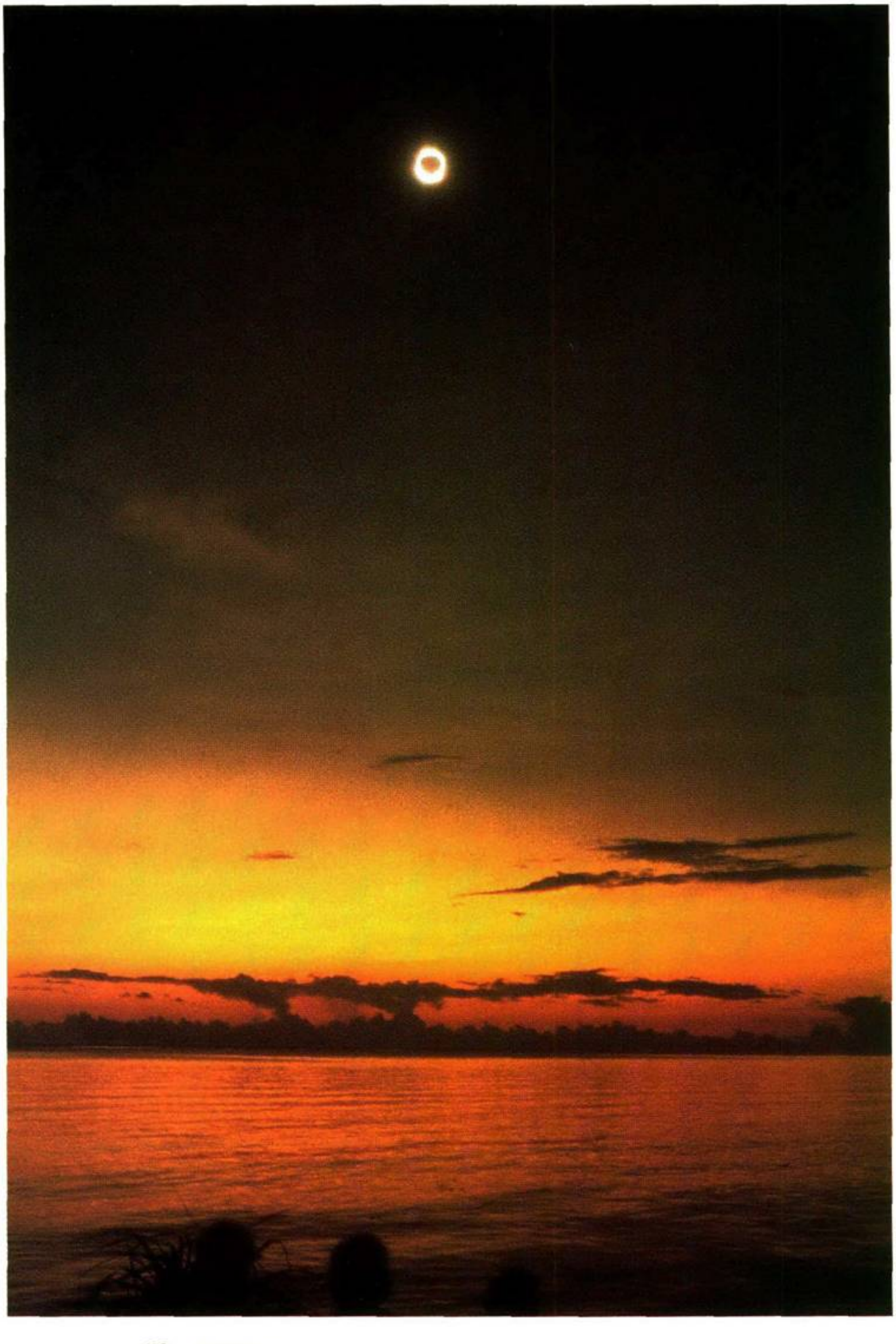
# Eye on the Sky

by Deborah Byrd

## A PARTIAL LUNAR ECLIPSE

A partial lunar eclipse takes place on the night of June 14/15, when the Moon slides into the dark shadow of Earth. This eclipse is visible from all of the contiguous United States and southern Canada. Total solar eclipses can be seen only by those standing inside a narrow path on Earth's surface, but lunar eclipses are a more global experience. They are visible anywhere the Moon is visible, from an entire Earth hemisphere. Your first awareness of a dark notch along the northern edge of the Moon — the first sign to most people that the eclipse has begun — may come at the exact moment that someone else a thousand miles away notices the same notch. It's almost as though the face of the Moon is a blank screen, on which we're all watching the same movie.

**A TOTAL SOLAR ECLIPSE** on June 30 will be witnessed by observers in South America and the South Atlantic Ocean. This photo is of the 1988 eclipse.



Carter Roberts

The time of the eclipse for you depends on your time zone. The Moon enters the darkest part of Earth's shadow at 11:27 p.m. EDT (8:27 p.m. PDT) on June 14. Mid-eclipse comes at 12:57 a.m. EDT on June 15. Then Earth's shadow covers 69 percent of the Moon's face. The Moon leaves this dark shadow at 2:27 a.m. EDT.

Take note of the darkness of the shadow during this eclipse. It may appear darker than usual, due to the sulfuric acid mist and fine particles of volcanic ash — known collectively to scientists as "aerosols" — blown into our planet's stratosphere during the eruption of Mount Pinatubo a year ago. In most lunar eclipses, some sunlight refracts through Earth's atmosphere into the shadow on the Moon's face. Volcanic dust may now be serving to block this effect.

Also, be aware that there is a lesser eclipse happening before and after the main event. Earth's shadow has two parts, a dark inner "umbra" and a lighter surrounding "penumbra." The Moon first enters the lighter penumbral shadow at 10:09 p.m. EDT. This shadow appears as no more than a dusky shade on the Moon's face. It is so subtle that many people claim to be unable to see it. Even this ephemeral shading is gone after 3:45 a.m. EDT.

The Moon is in a fairly distant part of its orbit on the night that the eclipse takes place. It may appear slightly smaller to you, compared with other Full Moons. On the night of the eclipse, the Moon is officially in front of the constellation Ophiuchus, not far from the bright star Antares in the constellation Scorpius. Also, this is the Full Moon nearest the solstice on June

20. The Sun rides high in the sky at the solstice, and the Full Moon is opposite the Sun. Thus the Full Moon of June always makes an exceptionally low arc across the sky as seen from the Northern Hemisphere.

Ivan Dryer

**EARTH'S SHADOW SWEEPS** across the Moon on June 15, creating a partial lunar eclipse that will be visible across the western United States. This photo is of the 1983 eclipse.

## MERCURY IN THE EVENING

This month the innermost planet Mercury begins one of its better evening apparitions for this year. That doesn't mean that the planet is fabulously noticeable, only that you can see it if you look for it.

If you watch the west-northwestern sky just after sunset during the second week of June, you'll see Mercury pop into view against a background of bright twilight. It starts out very low in the sky as June opens, but it creeps higher with the end of each new day. On June 16, look for Mercury to mark the bottom of an isosceles triangle with the stars Castor and Pollux in the constellation Gemini. On June 24 and 25, Mercury makes a line with these two stars. Afterward, the starry "eyes" of the Gemini twins drop into the Sun's glare, but Mercury remains visible in the west after sunset into July.

Mercury is highest in the sky toward the month's end, when it shines at magnitude 0.1. It's actually a bit higher up after sunset around June 27 than it is when at its greatest angular distance from the Sun — called its greatest elongation — on July 5.

## THE JUNE SOLSTICE

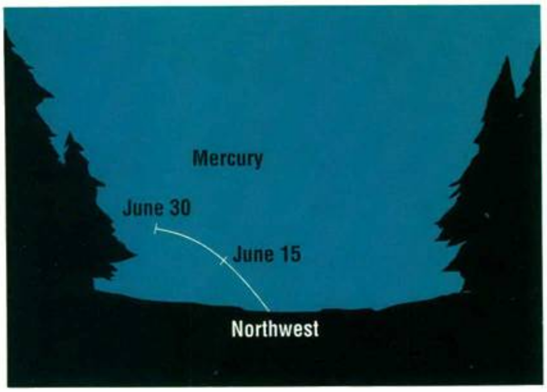
On June 20 at 11:14 p.m. EDT, the Sun reaches its most northerly point on the imaginary celestial sphere surrounding Earth. This is the June solstice, the first official day of summer in the Northern Hemisphere, and a hallmark in Earth's 600-million-mile orbit around the Sun. On this day, the Sun's rays extend across and beyond the North Pole, while falling short of the South Pole, reaching only the near side of the Antarctic Circle. At this solstice each year the North Pole basks in the light of a midnight Sun, while the South Pole freezes in noontime darkness.

Even if Earth didn't tilt on its axis, sunlight wouldn't fall evenly on our planet. Because Earth is round, sunlight would beat straight down at the equator, while only glancing off the poles. Earth's axial tilt complicates this picture. As Earth travels around the Sun, the Northern and Southern Hemispheres trade places in receiving the most direct rays of sunlight. It is the changing angle at which the Sun's rays strike Earth that gives us the change in the seasons.

Northern Hemisphere summer and Southern Hemisphere winter are technically the longest seasons. That's because in early July Earth reaches its aphelion or farthest point from the Sun. Thus slightly more time passes between the June solstice and September equinox than between any other solstice and equinox.

## JUNE'S PLANETS

**Mercury** can be found low in the west after sunset in the last three weeks of June and into July. It is brighter at the beginning of this period, but it is easier to see in late June because it is higher in the sky. The last of the winter stars slide down behind Mercury and disappear into the twilight this month. The planet is 5° south of Pollux on June 22.



**MERCURY GLIDES** into the early evening sky this month, achieving its greatest elevation 30 minutes after sunset on June 30. Try spotting it low in the northwest with a pair of binoculars. Then see if the planet is visible with the eye alone.

By the end of the month, **Jupiter** is bearing down on Mercury from slightly higher in the west after sunset. The two planets are separated by 35° on June 30. The giant planet is easy to see throughout June. It shines very brightly at magnitude –2.0 in the constellation Leo. Jupiter is still near Leo's brightest star, Regulus, sometimes called "the heart of the Lion." It will follow this star into the Sun's glare in August. Look for Jupiter near the waxing Moon on the night of June 6.

**Saturn** is now becoming more prominent in preparation for its August opposition. It brightens from magnitude 0.7 to 0.5 this month. Early in the month it rises around midnight, but you'll find it in the east-southeast only about two hours after sunset by the month's end. Saturn is in the constellation Capricornus, the Sea Goat of ancient mythology, whose shape resembles an arrowhead. Saturn rises near the Moon late at night on June 18/19. You can see Saturn in the southern sky at dawn this month.

While all the other planets pursue their steady courses across our sky, **Mars** lingers near the fiery glow of the coming dawn. It is now coming up about three hours before the Sun and appears low in the east before sunup, shining at magnitude 0.9. It seems as though Mars will never leave this location in our sky! But by the end of summer, you'll notice that Mars suddenly seems to be getting much brighter. What's happening is that Earth is creeping closer to Mars in our smaller, faster orbit. Our faster motion will cause Mars to sweep over into the evening sky this fall. It'll dazzle us at opposition in early 1993. This month, Mars is still moving rapidly eastward in front of the stars, and it passes from Pisces into Aries. Look for Mars near the waning Moon on the morning of June 26.

**Venus** cannot be seen this month. From Earth's vantage point, it is behind the Sun, in superior conjunction, on June 13.

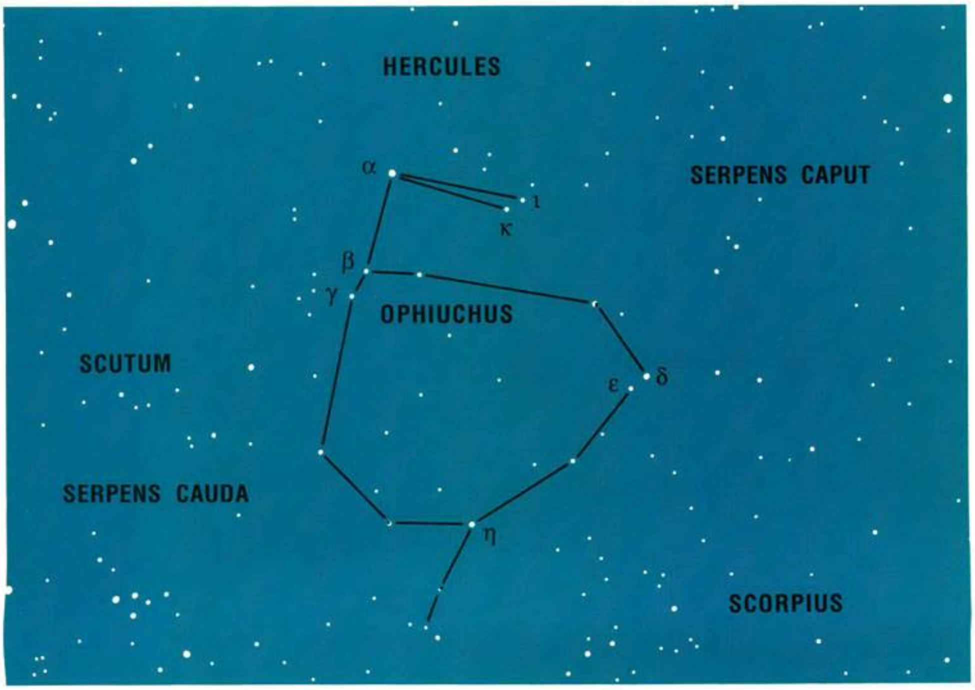
## *THE STARRY SKY*

This month's lunar eclipse takes place at the feet of the constellation Ophiuchus the Serpent-Bearer. This constellation sprawls over such a large area of the sky and is generally so faint that you may never have gotten a good look at it. Especially if you are in a country location, be sure to trace the outline of this mighty star figure as the sky darkens during the eclipse.

Ophiuchus is joined in legend and in the sky to the constellation of the Serpent. The western part of the snake's body is the serpent's head, Serpens Caput. The eastern part is the tail, Serpens Cauda. There are many who disagree, but to me Ophiuchus looks just like a giant man grappling with a snake. The name Ophiuchus comes literally from the Greek phrase meaning "the man that holds the serpent."

In Greek mythology, the constellation Ophiuchus is identified with Aesculapius, said to have been the first doctor. According to the legend, Aesculapius killed a snake. Almost immediately another snake carrying an herb in its mouth slithered into the room. This herb revived the dead snake. Aesculapius studied the herb and learned about its healing powers. He became a great healer, expert at saving lives. But this infuriated Hades, god of the underworld, and he persuaded Zeus to kill the doctor with a thunderbolt and place him in the heavens. This legend has given rise to a typical symbol of medical professionals: a staff with a serpent wound around it. □

**OPHIUCHUS THE SERPENT-BEARER** is one of the prettiest constellations of early summer. With a torso composed of a group of ten bright stars, it is surrounded by Serpens, Scutum, Scorpius, and Hercules.



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*Deborah Byrd's new radio series, "Earth and Sky," can be heard on stations in the United States, Canada, and Guam.*

## Through the Eyepiece

**by Rick Shaffer**

### THE MOON CRUISES THROUGH THE UMBRA

For most of us, June means the first month of observing unhindered by a variety of problems. The year's weather has gone through adolescence into the prime of its life. Except for those of us who go to the mountains to observe, it's finally warm at night! Adding to our enjoyment of the season is a potentially dark partial lunar eclipse.

Mark Payne-Gill

**DARKNESS OVERTAKES THE MOON** on the evening of June 14, when a partial eclipse obscures 65% of the Moon's surface at maximum eclipse.

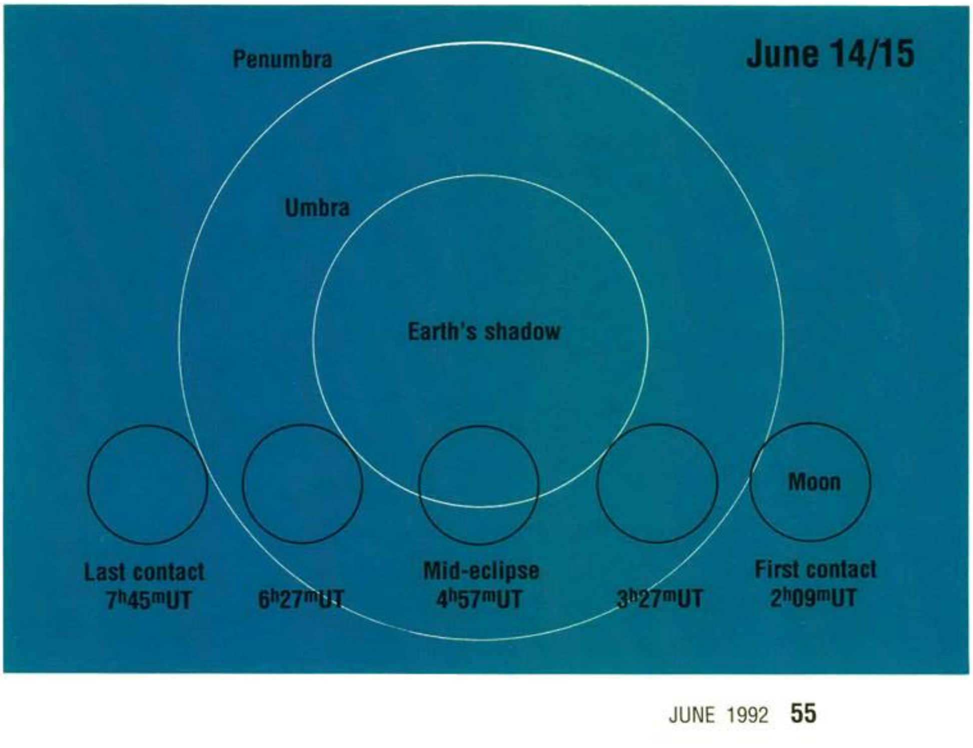
With the exception of our friends in the frozen North, all of us in North America will see at least part of the passage of the Moon through the southern edge of Earth's shadow on the night of June 14/15. This event precedes by one-half lunation the total solar eclipse of June 30, which will be observed mostly by the denizens of the South Atlantic, as the shadow touches land only in scenic Uruguay, just after sunrise.

Two aspects of a lunar eclipse attract viewers year after year: the color of the light within the shadow and the relentless march of Earth's shadow across the lunar disk. The fact that light fills Earth's shadow during a lunar eclipse is caused by Earth's atmosphere. If Earth lacked an atmosphere, the shadow's edge would be sharp, dulled only by the effects of diffraction. In reality, however, our atmosphere refracts some of the Sun's light into the shadow, which means that the Moon never really disappears during an eclipse.

The darkness of any lunar eclipse is strongly affected by what will be going on in Earth's atmosphere at the sunrise/sunset line around the planet. That's the strip around Earth where the Sun's light refracts into the shadow. If the atmosphere is filled with clouds along much of the strip, less light will get through and we'll have a dark eclipse. If not, the eclipse will be relatively bright.

Another element controls both the darkness and the color of a lunar eclipse: the amount of dust and volcanic ash in the atmosphere. The dust and ash particles are considerably larger than the wavelength of light at the blue end of the visible spectrum, so those wavelengths are effectively blocked as the light passes through the atmosphere.

**THE MOON'S APPARENT PATH** through Earth's umbral and penumbral shadows is shown in this diagram.



Light toward the red end of the spectrum has a longer wavelength and is not blocked as easily by the particles, so much more red light makes its way through the atmosphere to fill the shadow. Quite a bit of yellow light, whose wavelength is almost as long as red, gets through to fall on the Moon's disk. Therefore, reds and yellows are the dominant colors in a lunar eclipse. To emphasize the colors of the eclipse, use the lowest power your telescope is capable of providing. Also, be sure to view the eclipsed Moon in your binoculars or finderscope.

June's lunar eclipse could be quite dark, due to the large amount of fine ash deposited in the atmosphere by the eruption of Mount Pinatubo in the Philippines last year. In photographing the partially eclipsed Moon, especially through your telescope, you'll see enough light to use relatively short exposures. In fact, the built-in light meter in your camera should allow you to determine the exposure needed without resorting to a table.

Remember, however, that there is a big difference in the brightness of the Moon's surface between the part in the umbra and the part in the sunlight. So be sure to take exposures at least two stops on either side of that indicated by the meter, then one stop, and so on.

Although timing the ingress of a crater into the umbra is no longer of any particular scientific value, I still find it fascinating to watch the onrushing shadow swallow up crater after crater. You may too.

## *A RARE APPEARANCE BY MERCURY*

Conventional wisdom says that Mercury makes good evening apparitions only in the spring and good morning apparitions in the autumn. That's because the ecliptic makes its biggest angle with the horizon at those times and, thus, Mercury doesn't waste its meager angular displacement from the Sun by trying to stretch it along the horizon. Conventional wisdom isn't always completely correct, however, as Mercury's evening apparition this month demonstrates. Beginning at mid-month and extending into the first week of July, you can find Mercury just after sunset. Here's how:

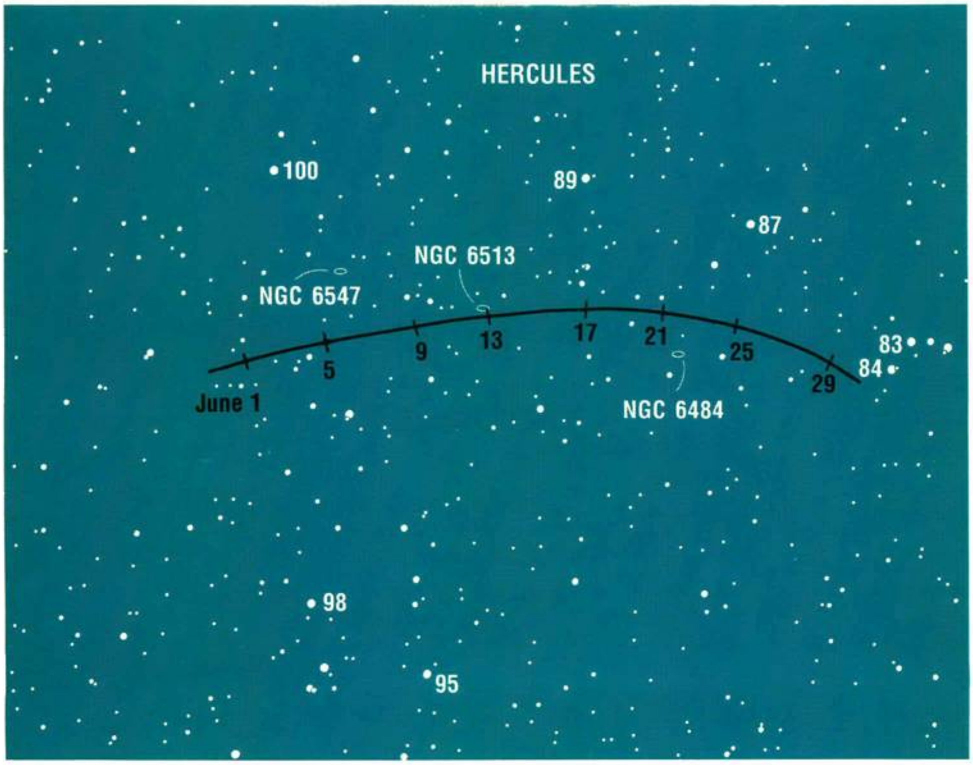
There's seldom much time, so set up your telescope before sunset. Because Mercury doesn't get very high in the sky, be sure to select an observing site that allows you an unobstructed view of the western horizon. Once you've satisfied that criterion, another is to try to avoid sources of heat. They ruin the seeing. If you can, accurately align your equatorial mount the night before so you can use setting circles to aid in finding Mercury. If you're not using setting circles, be sure to locate the point on the horizon where the Sun sets. You should be able to find Mercury by looking just east of that point thirty minutes after sunset. (You can begin looking a bit earlier when Mercury will, of course, be a bit higher.)

One nice feature about an apparition of Mercury is that you can see as much of its full range of phases as possible in just a few weeks. So if you first find this shy planet at mid-month, you'll see the phases go from a waning gibbous to past "half-moon" in the space of three weeks. Aside from the phases, note that Mercury's rough surface scatters much of the shorter (blue) wavelengths of the Sun's light while reflecting the longer wavelengths more faithfully. We see this as Mercury's distinctly yellowish cast.

### COORDINATES FOR PALLAS

| Date | R.A.(2000.0)Dec. | |
|---|---|---|
| June 1 | 18h08.9m | +24°17' |
| June 5 | 18h05.8m | +24°33' |
| June 9 | 18h02.6m | +24°44' |
| June 13 | 17h59.2m | +24°51' |
| June 17 | 17h55.8m | +24°53' |
| June 21 | 17h52.4m | +24°50' |
| June 25 | 17h49.1m | +24°42' |

**TRY SPOTTING ASTEROID PALLAS** as it reaches opposition this month. The distant hunk of rock will glow at magnitude 9.4, making it an easy target for binoculars and small telescopes.



## *THE LAST OF OLD JOVE*

Jupiter was at quadrature with the Sun on May 26 and is thus high in the sky after sunset throughout June. However, this is the last month for serious observations of our largest planet, because it will be quite a bit closer to the horizon next month and almost lost in the proverbial "solar glare" in August. Plan to make Jupiter your second target after Mercury during the last half of June. Doing so will allow you to observe it while it is high in the sky and above much of the bad seeing near the horizon.

Jupiter's equatorial diameter as seen this month ranges from 36" to 33". So even if your seeing is marginally good, you should see details of approximately 3 percent of the diameter of Jupiter's disk.

The Great Red Spot is the wild card as this cyclonic storm wedges its way along the South Tropical Zone while spilling over into the South Equatorial Belt. The "movies" made from images taken by the Voyager spacecraft as they approached Jupiter in the late 1970s show the Great Red Spot gobbling up smaller dark spots and then spitting them out. Because these movies are speeded up from real time, they are quite vivid. But you can see a lot of this immense, distant storm from your own backyard.

## SUMMER STAR PARTY TIPS

With the arrival of summer, you may get the chance to attend a star party with your astronomy club or simply a group of friends. It's important to take careful looks through the eyepiece and think about what you're seeing. And don't take a short look, either: slowly drink in the view. Study the details you see in the eyepiece carefully and ask questions of the telescope owner about objects and the equipment you're using. That way you'll get a good feeling about how different objects look through different instruments.

More than anything, make sure you enjoy yourself this summer. Amateur astronomy is a relaxing, enjoyable, and stimulating way to spend your time.

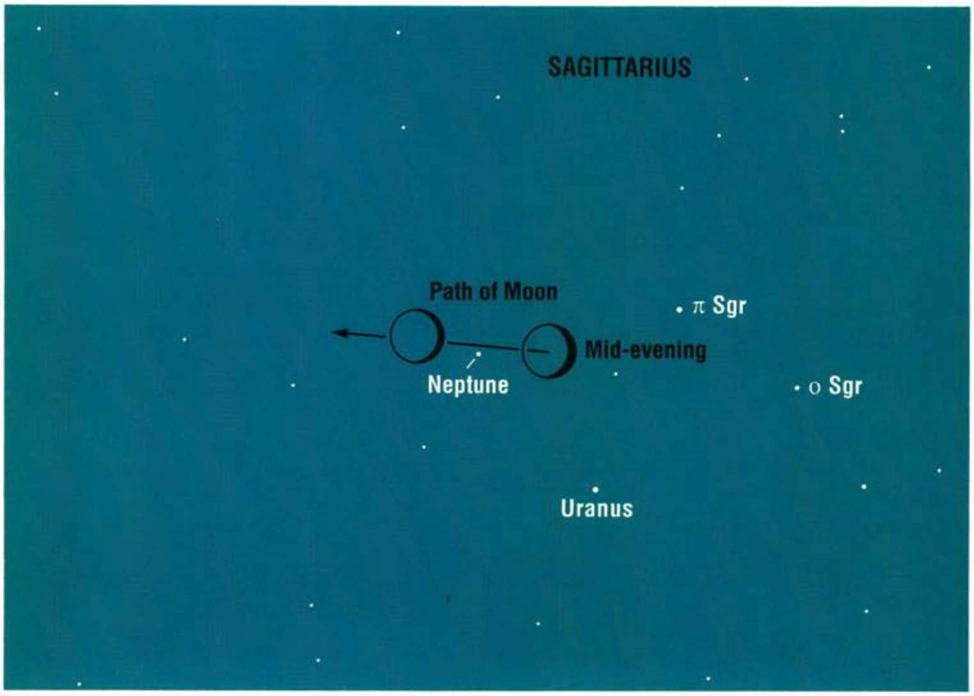
## PLANETS IN THE EYEPIECE

While June finds **Mercury** making a modest splash, **Venus** lurks so close to the Sun that it's really not visible. **Mars** lies in Pisces, but its 6" disk will show you little in the way of interesting detail. Its poor position near the horizon in the morning also argues against devoting much, if any, time to it.

**Saturn** is finally high enough in the sky to warrant serious attention, although you'll still have to wait until well after midnight for the ringed planet to transit the meridian. Saturn's 17" disk and 40" rings make it a fine object in any telescope, and, since you'll be observing it after midnight when the seeing can be expected to be good, you should see quite a bit.

Since Saturn produced a Great White Spot almost two years ago, observers have shown renewed interest in viewing not just the rings of Saturn, but also the belts and zones on the planet itself. Although they are more subtle than those observed on Jupiter, they can be very interesting. Try using a variety of filters to observe the belts and zones on Saturn. Many observers find that a blue filter makes features near the red/yellow end of the spectrum appear darker than the rest of the features, effectively enhancing contrast.

You'll find Saturn in Capricornus, where it will outshine any of that constellation's stars. While waiting for Saturn to reach the meridian, you can also take a look at Uranus and Neptune, which may be found in eastern Sagittarius, just south and east of the 3rd-magnitude star Pi Sagittarii.



**AN OCCULTATION OF NEPTUNE** by the Moon occurs on June 16. Begin watching the bright limb of the Moon as dusk falls and you will see Neptune slip behind the Moon. Reappearance from behind the Moon's dark limb takes place under a dark sky.

## ASTEROIDS IN THE EYEPIECE

June finds 2 **Pallas**, the second asteroid to be discovered, reaching opposition on the 18th of the month. You can find this 9.4-magnitude chunk of primordial debris by using the map on page 56. Note that this chunk is a bit more than 375 miles in diameter. ☐

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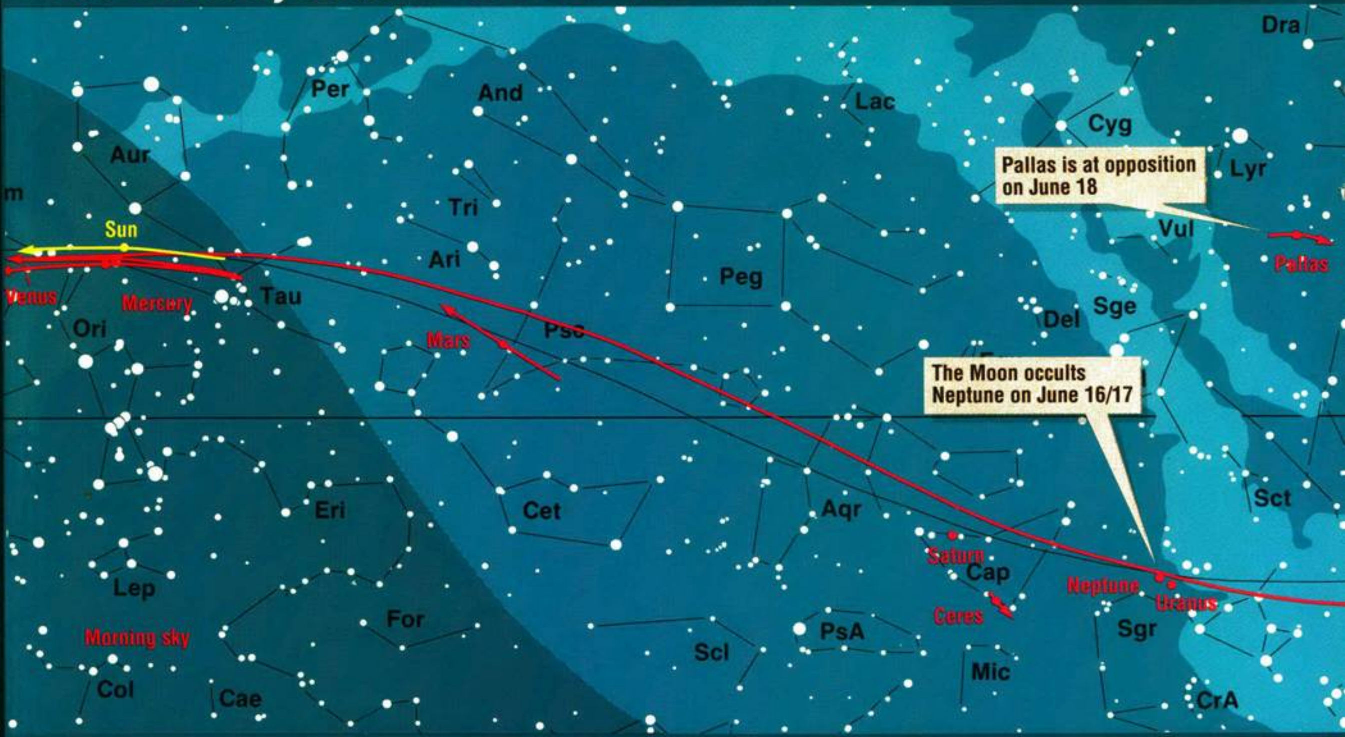
*Rick Shaffer is a freelance writer and runs his own astronomy product design firm in Altadena, California.*

# The Solar System June 1992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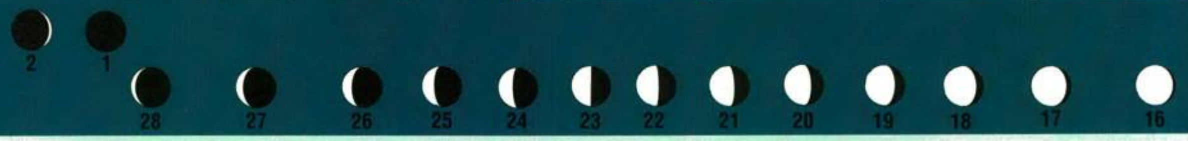
Pallas is at opposition on June 18

The Moon occults Neptune on June 16/17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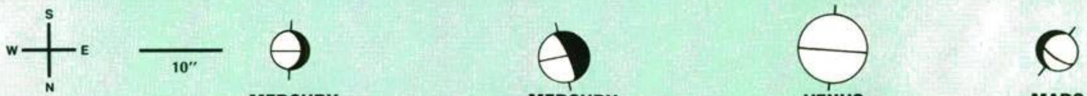
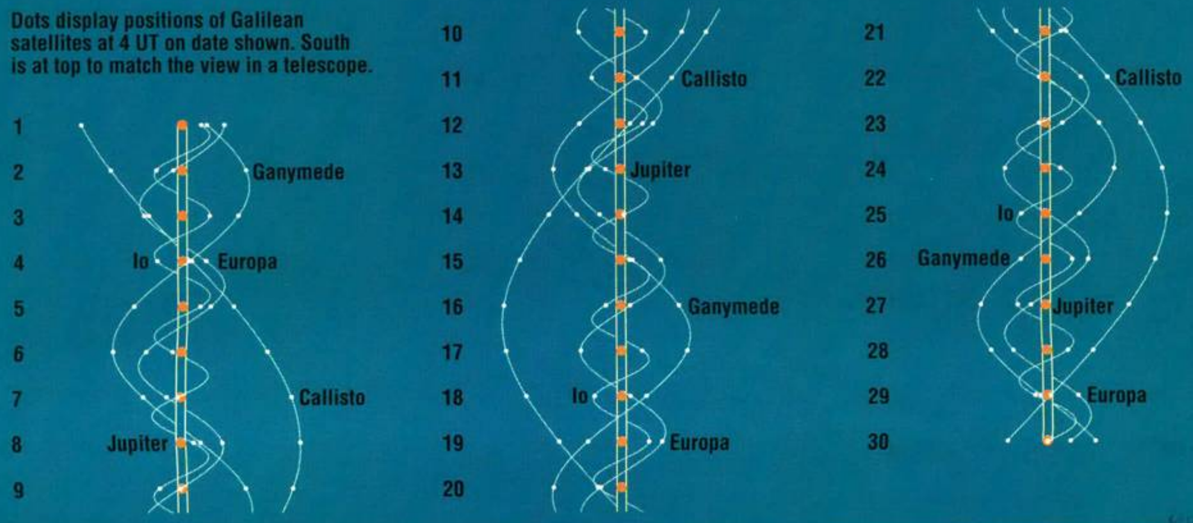
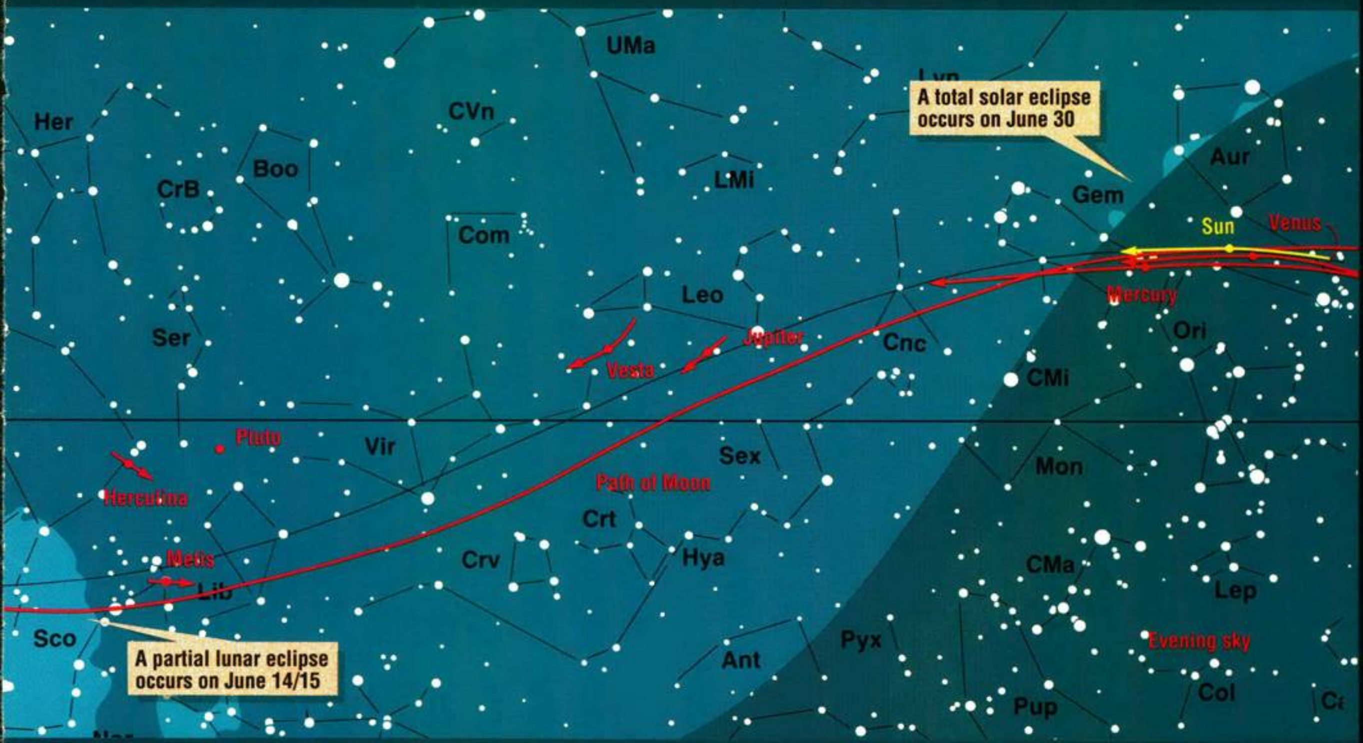


| Planet | MERCURY | MERCURY | VENUS | MARS |
|---|---|---|---|---|
| Date | June 15 | June 30 | June 15 | June 15 |
| Magnitude | -0.8 | 0.2 | -3.9 | 0.9 |
| Angular Size | 5.7" | 7.2" | 9.6" | 5.5" |
| Illumination | 80% | 52% | 100% | 90% |
| Distance (AU) from Earth | 1.186 | 0.933 | 1.736 | 1.716 |
| Distance (AU) from Sun | 0.353 | 0.433 | 0.719 | 1.387 |
| Right Ascension (2000.0) | 6h45.7m | 8h25.1m | 5h36.5m | 1h54.7m |
| Declination (2000.0) | +20°13' | +20°13' | +23°32' | +10°26' |

## Jupiter's Moons


Dots display positions of Galilean satellites at 4 UT on date shown. South is at top to match the view in a telescope.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Mercury
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Vesta
Cnc
Ori
CMi
Pluto
Vir
Sex
Mon
Herculina
Path of Moon
Crt
Metis
Lib
Crv
Hya
CMa
Lep
Sco
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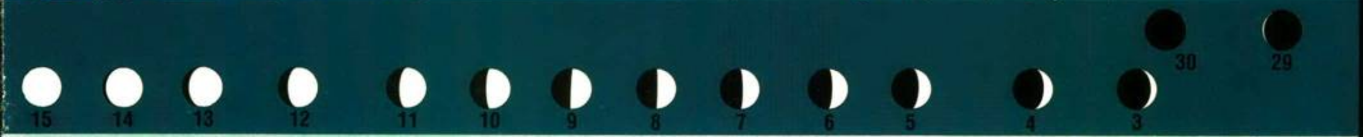
Pyx
Evening sky
Col
Pup

A total solar eclipse occurs on June 30

A partial lunar eclipse occurs on June 14/15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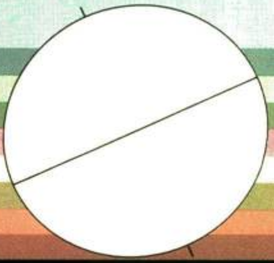
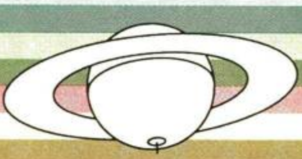
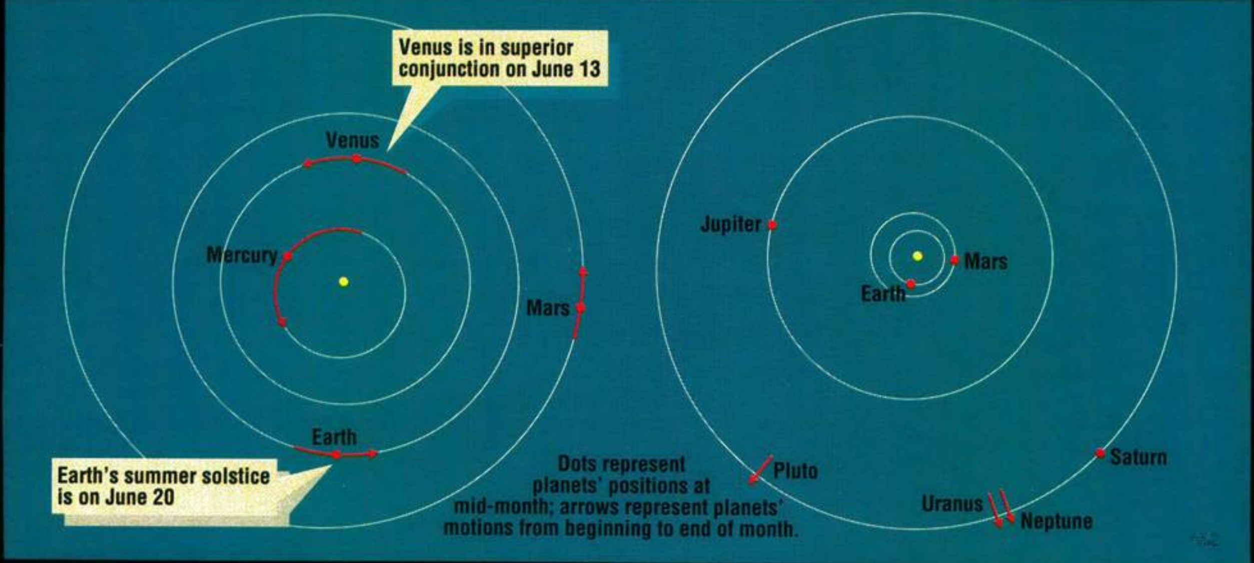




| JUPITER | SATURN | URANUS | NEPTUNE | PLUTO |
|---|---|---|---|---|
| June 15 | June 15 | June 15 | June 15 | June 15 |
| -1.9 | 0.6 | 5.6 | 7.9 | 13.7 |
| 35.0" | 17.8" | 3.8" | 2.3" | 0.1" |
| 99% | 100% | 100% | 100% | 100% |
| 5.625 | 9.276 | 18.598 | 29.261 | 28.877 |
| 5.423 | 9.906 | 19.538 | 30.191 | 29.701 |
| 10h39.0m | 21h24.2m | 19h14.0m | 19h18.9m | 15h29.2m |
| +9°47' | -16°11' | -22°47' | -21°27' | -3°19' |

## The Planets in Their Orbits


Venus
Mercury
Mars
Earth
Jupiter
Mars
Earth
Pluto
Saturn
Uranus
Neptune

Venus is in superior conjunction on June 13

Earth's summer solstice is on June 20

Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

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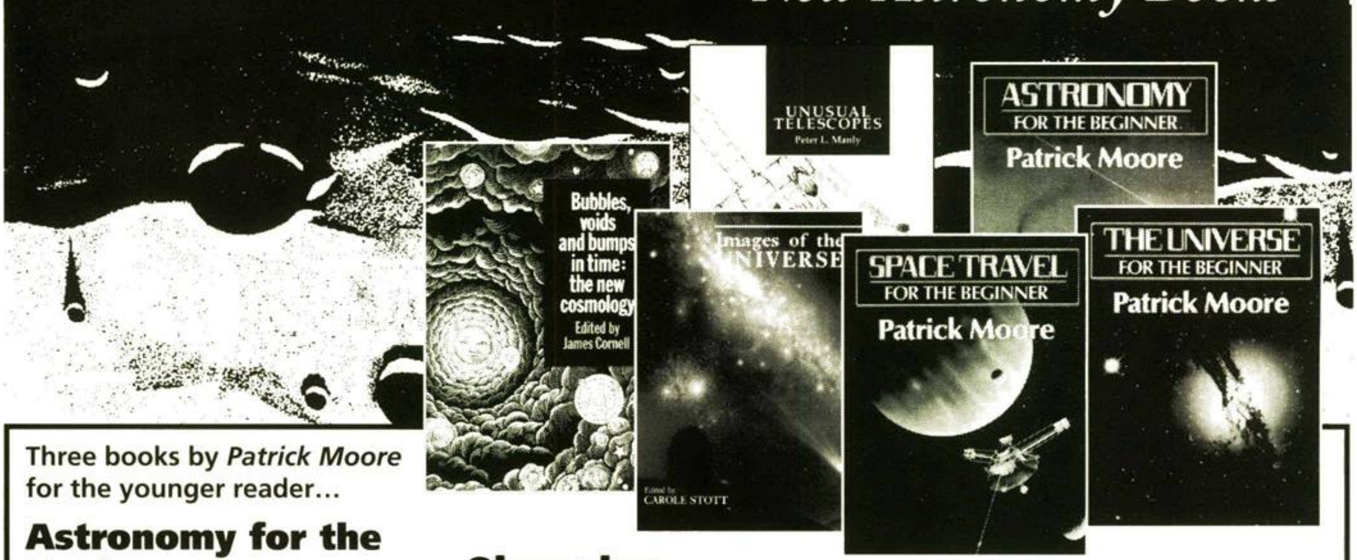

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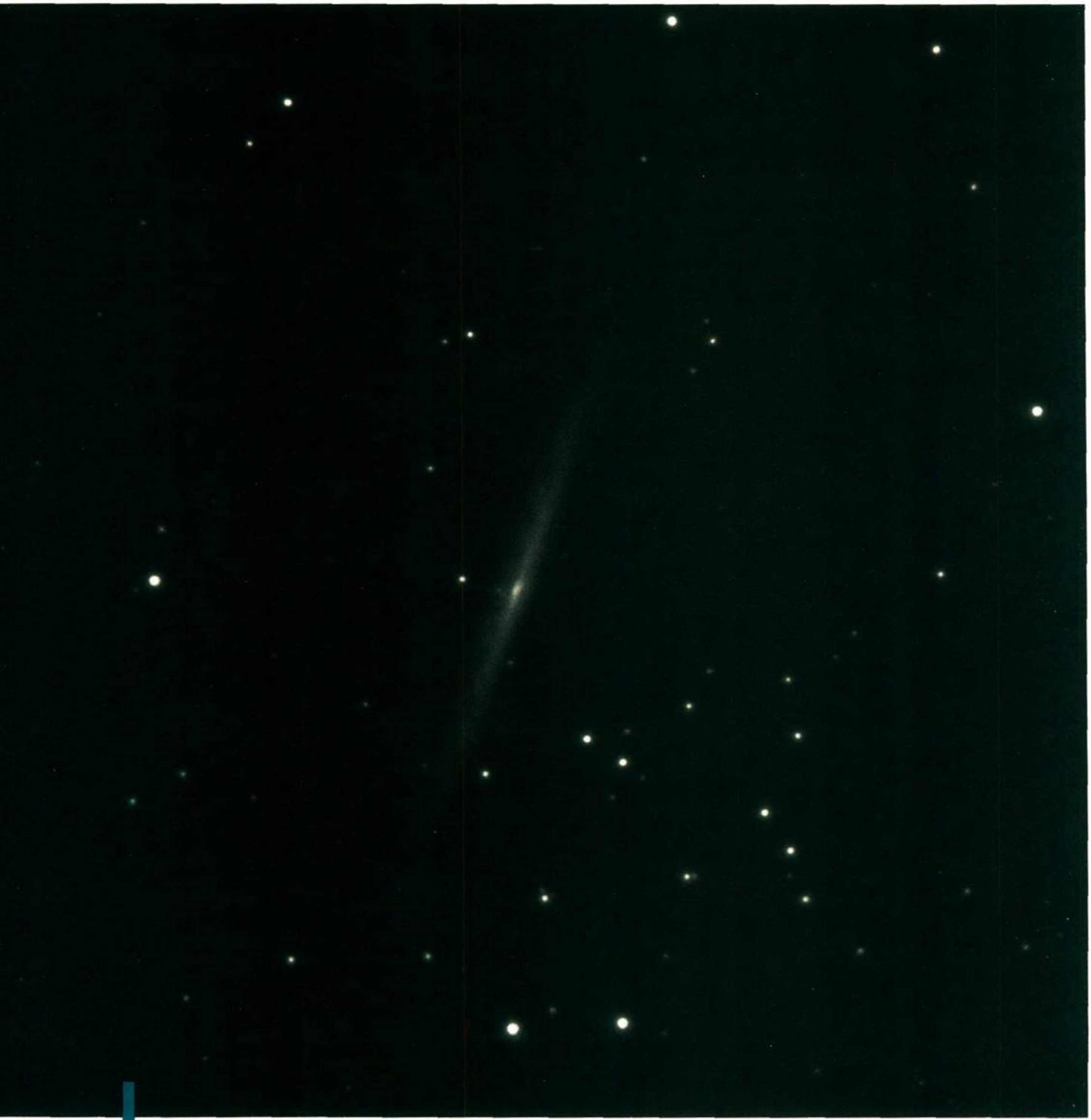
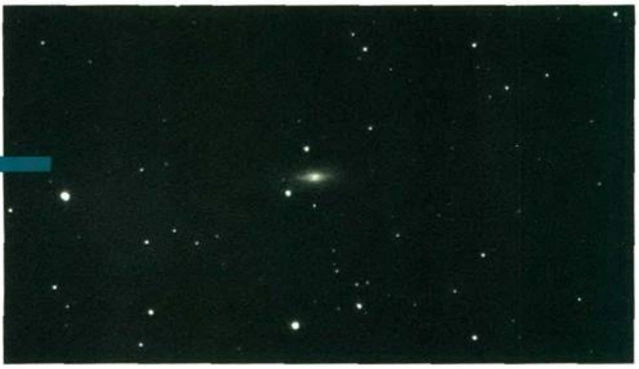


**NGC 5907**

Mag 10.4

Size 12.3' by 1.8'

by Bill Iburg



**M102 (NGC 5866)**

Mag 10.0

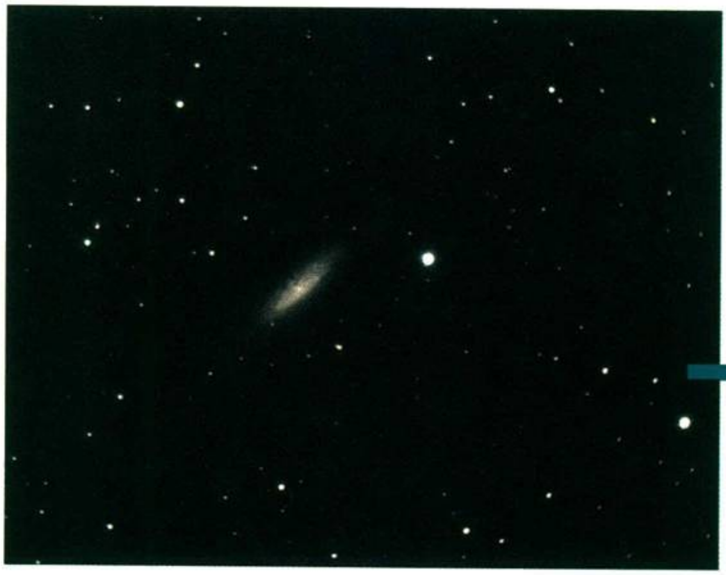
Size 5.2' by 2.3'

by Jack Newton

# DISCOVER DRACO's WELL-KEPT SECRETS

Tucked away in the inconspicuous constellation Draco are some of the sky's best (but rarely observed) galaxies.

by Richard W. Jakiel



## NGC 6503

Mag 10.2
Size 6.2' by 2.3'
by Bill Iburg

Warm summer nights offer an amazing array of deep-sky objects to explore with a telescope. Bright globular clusters like M5 and M13 lie high in the sky, and the great star clouds that delineate the Milky Way rise in the east. Star clusters and nebulae, missing from the spring skies, come into view. Nearly all types of deep-sky objects scatter across the heavens during these balmy nights. With the apparent exception of galaxies.

Galaxies do float about the summer sky, but most are blocked by the thick clouds of stars and dust in the Milky Way Galaxy. One of the greatest clumps of bright galaxies we are able to see this time of year is the beautiful collection of spirals and ellipticals in Draco. Although Draco appears to the naked eye as a rather dim star group winding around the pole, it presents a vast domain rich in memorable galaxies to the telescope user armed with a star atlas.

The largest galaxy in Draco is **NGC 4236**, a huge, loose spiral located in the last "segment" of the dragon's tail, between the stars Kappa and Lambda Draconis. To find NGC 4236, locate Kappa and sweep about 1.5° west and then shift about 15' south. Use low power first to see the dim glow; then switch to medium power to examine surface details. A large, outlying member of the M81/M82 group of galaxies, NGC 4236 is also a close neighbor to our own small group of galaxies. The M81 group, only 7.5 million light-years distant, also includes NGC 2403 and NGC 2366. Photographs show NGC 4236 as a large, loose spiral with fragmented arms containing knotty clumps of stars and gas. NGC 4236 glows at magnitude 9.6 but has a low surface brightness because its light spreads over 18.6' by 6.9'. Visually, this object reminds me of the large, dim giants of the Sculptor group of galaxies. In a 10-inch scope, I see a very large, dim glow oriented nearly north-south with a low contrast, barlike center. In large backyard scopes you may see some low contrast knots and dark rifts.

Sweeping your telescope eastward, locate the star Iota Draconis near the Bootes-Draco border. Here you'll find two small clusters of bright galaxies whose members are among some of Draco's best known deep-sky objects. **M102** (NGC 5866), a spindle-shaped galaxy bright enough to see in binoculars, is part of a small cluster of galaxies about 35 million light-years distant. M102 lies about 3.5° southwest of Iota Draconis, glows at 10th magnitude, and measures 5.2' by 2.3'. Start your star-hop to this galaxy from a 5th-magnitude star on the Bootes-Draco border. M102 lies a mere 1.3° north of this star.

Considerable controversy surrounds NGC 5866, as some astronomers consider it one of the "lost" Messier objects. In the mid-19th century William H. Smyth suggested that NGC 5866 was originally logged by Messier's assistant Pierre Mechain as M102. Later in this century, this assumption proved wrong. Instead, when Mechain observed a 102nd object in the catalog, he was actually viewing M101, a large spiral in Ursa Major that he had already observed. The label M102 stuck, however, and cataloguers and writers have called this galaxy M102 for decades.

Unlike most galaxies viewed through a telescope, M102 resembles its appearance in photographs. Photographs reveal an elongated elliptical or lenticular (type S0) galaxy with a thin equatorial dust lane. M102's lens shape, typical of S0 galaxies, is visible in small backyard scopes. With a 4-inch scope, you'll notice the galaxy's spindle shape and sharply pointed ends. M102's high surface brightness allows for use of greater magnifications than you normally use when viewing galaxies. Observers with dark skies and scopes larger than 12.5 inches in aperture may see the narrow dust lane that bisects M102 lengthwise. With a 20-inch scope at 175x, I saw a beautiful spindle shape with a razor-sharp dust lane.

## GALAXIES IN DRACO

| Galaxy | R.A. (2000.0) Dec. | Mag. | Size |
|---|---|---|---|
| NGC 4125 | 12h 08.1m +65°11' | 9.8 | 5.1' by 3.2' |
| NGC 4236 | 12h 16.7m +69°28' | 9.6 | 18.6' by 6.9' |
| M102 | 15h 06.5m +55°46' | 10.0 | 5.2' by 2.3' |
| NGC 5879 | 15h 09.8m +57°00' | 11.5 | 4.4' by 1.7' |
| NGC 5905 | 15h 15.4m +55°31' | 12.3 | 4.2' by 3.3' |
| NGC 5907 | 15h 15.9m +56°19' | 10.4 | 12.3' by 1.8' |
| NGC 5908 | 15h 16.7m +55°25' | 11.9 | 3.2' by 1.3' |
| NGC 5981 | 15h 37.9m +59°23' | 13.0 | 2.8' by 0.6' |
| NGC 5982 | 15h 38.7m +59°21' | 11.1 | 2.9' by 2.2' |
| NGC 5985 | 15h 39.6m +59°20' | 11.0 | 5.5' by 3.2' |
| NGC 6503 | 17h 49.4m +70°09' | 10.2 | 6.2' by 2.3' |
| NGC 6643 | 18h 19.8m +74°34' | 11.1 | 3.9' by 2.1' |

## NGC 5985

Mag 11.0

Size 5.5' by 3.2'

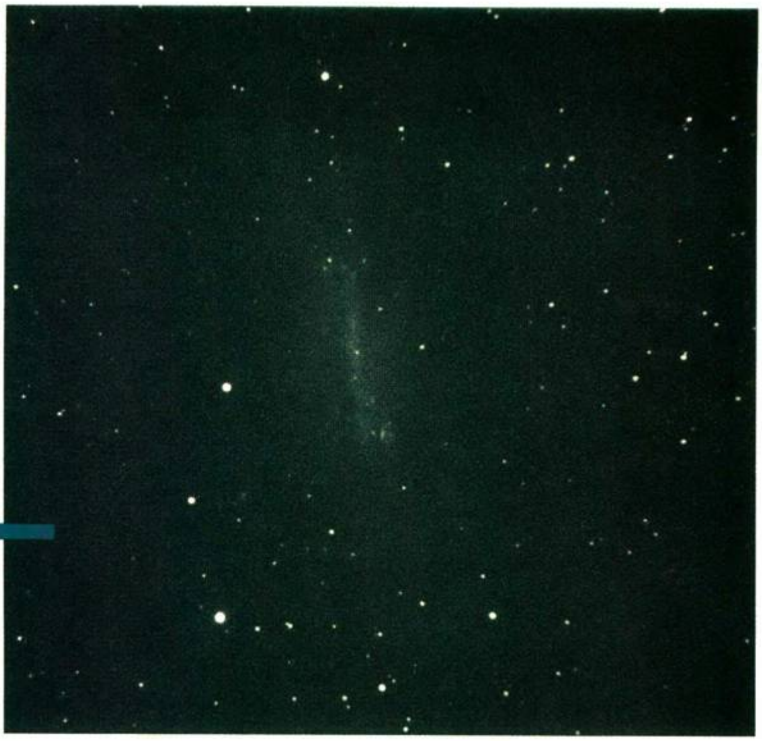
by Kim Zussman

## NGC 4236

Mag 9.6

Size 18.6' by 6.9'

by Martin C. Germano



The most impressive galaxy in the group of galaxies surrounding M102? **NGC 5907**. This huge dusty spiral spans over 12', nearly half the size of the Moon. Lying about 2° east-northeast of M102, it offers unusual detail and is reasonably bright, making it an outstanding object to sketch or photograph. A small scope reveals a long dusty streak with a small bright core. A large backyard scope — 16 inches or more — reveals this galaxy in all its splendor. When I first viewed it with a 20-inch scope, I saw a bright, highly elongated object of even thickness and a central hub with a slight bulge. An irregular dust lane cuts across the galaxy, giving it a mottled appearance.

**NGC 5905** and **NGC 5908** might belong to the same galaxy group. NGC 5905 is a small, face-on barred spiral, while the other galaxy is a tilted spiral. Both have much higher recessional velocities than the other galaxies in the area and probably do not belong to the group, but constitute a background pair. NGC 5905 lies about 50' south of NGC 5907 and appears as a modest, 12.3-magnitude smudge elongated northwest-southeast. The rather bright central bar contains a small dense core. The galaxy's face-on orientation provides a good contrast to the large edge-on systems that make up the rest of the group. NGC 5908 lies in the same field as 5905, about 12' to the southeast. Its higher surface brightness disk appears distinctly elongated. Observers with modest backyard scopes should have no problem picking out this distant double system under relatively dark skies.

Another small group of galaxies can be found nearly 2° east of Iota Draconis. Although close neighbors in the sky to the M102/NGC 5907 group, galaxies **NGC 5981**, **NGC 5982**, and **NGC 5985** lie in the distant background relative to the M102 group. This tiny trio spans less than 20', so all three members fit in the field of a medium power eyepiece. Take note of their various orientations and shapes as you observe them. The most impressive member, NGC 5985, displays fine, tightly wound arms. At magnitude 11.0, it outshines several of the better known Virgo galaxies. Smaller telescopes will have little difficulty showing a bright oval nebulous patch oriented north-south. The small bright core readily stands out from the surrounding halo. In large backyard scopes, this galaxy has a mottled texture and traces of the spiral structure may be visible.

The middle member, NGC 5982, is a small elliptical galaxy. The galaxy's appearance, typical of ellipticals, is aperture independent. In other words, the galaxy appears about the same in small and large telescopes. Small and relatively bright, this galaxy is an easy target even in suburban skies. You should be able to see a small, slightly oval object with a very bright round core. The westernmost member, NGC 5981, is a delicate edge-on Sc spiral galaxy. At only 13.0 magnitude, its wispy streak of nebulosity surrounds a tiny stellar core. This silvery needle is 2.8' long but only 0.6' wide, making an interesting contrast to the more face-on spiral, NGC 5985. Several other faint members of this group are visible in this region. These faint galaxies require large backyard scopes to be seen.

Our last galaxy, **NGC 6503**, can be found in a line between the bright stars Psi and Omega Draconis. I find it easiest to start from Omega and star-hop north to a 6th-magnitude star. From here, move another 30' north and sweep to the east about 1.3° until you see a nebulous patch of light. Old references classify this galaxy as an Sc spiral, but photographs show tightly wound arms with a prominent central hub. Hence, the galaxy has been reclassified as an Sa spiral. With a magnitude of 10.2, NGC 6503 is brighter than many of the more famous Messier galaxies. Observing NGC 6503 with a medium-sized backyard scope shows a bright oval region elongated about 3:1 with an indistinct nucleus. With a large scope the galaxy's outer envelope appears mottled.

Draco is a hidden wonderland. Although it appears drab to the naked eye, the constellation offers a rare selection of bright galaxies for small telescope observers. Give yourself the opportunity to see some galaxies during a time when star clouds and nebulae dominate the evening sky. □

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*Richard W. Jakiel is a graduate student in Atlanta, Georgia, with years of experience as a deep-sky observer. His last article was "Galaxy Hunting in the Great Bear" (May 1991 issue).*

# Exploring the Summer Sky

Bright constellations and the glorious summer Milky Way await those who turn their eyes skyward on warm summer evenings.

by Deborah Byrd

Summer is the time for taking things easy. People sit outside after dinner. It's hard to put the kids to bed; after all, who can sleep when it's still light outside? Though darkness seems to take forever, by 10 or 11 p.m. the stars are glittering overhead. You can stand outside without a jacket and gaze upward, drinking in the glorious sights of the summer sky with just your naked eye.

From a very dark location in early June, you can see a glow just above and paralleling the eastern horizon. This is an edgewise view into our own Galaxy: the summer Milky Way. The starlit band of the Milky Way rises higher both as night passes and as summer progresses. It is a region rich in wonders, but let it wait a bit while you begin your evening exploration by looking to the west.

At this time the western sky contains the last of winter's stars. Golden Capella appears just above the northwestern horizon and will sink below it shortly. Though it is the sixth-brightest star in the sky, Capella doesn't appear that bright because of the obscuring haze low in the sky. To its left are the bright stars Castor and Pollux, the starry eyes of the Twins in the constellation Gemini. Alphard, in the neck of Hydra, is doing a nosedive in the west. As the minutes and hours tick by, Earth's eastward spin on its axis will carry all of these objects out of view. Later this summer, Earth's motion in orbit around the Sun will bring the Sun between us and them.

Many of the constellations associated with spring have now crossed the "meridian" — the line that divides the sky in half from due north to due south. Look for Leo the Lion above Alphard in the west. It contains a recognizable pattern of stars, or "asterism," in the shape of a backward question mark. This pattern is called the Sickle, and it now appears to be slicing down toward the western horizon. At the base of the Sickle lies Regulus, the brightest star in Leo and the one that represents the lion's heart. Regulus is a blue-white star that shines at magnitude 1.4 from a distance of about 90 light-years. Though Regulus is bright, it pales in comparison to the planet Jupiter, which happens to lie within the boundaries of Leo this year. The lion's tail is represented by 2nd-magnitude Denebola, which is located above and slightly left of Regulus on the sky's dome. This white star lies approximately 40 light-years away.

You can imagine Regulus forming a large triangle with two other bright stars, both located 55° to 60° east of the lion's heart. (This is equivalent to three to four handspans. A handspan is the angular distance between the

Robert Nelson

**CYGNUS PLAYS TWO ROLES** in the summer sky — one is that of a swan, the other that of the Northern Cross.

tips of your thumb and pinkie when you hold your outstretched hand at arm's length. For most people, a handspan covers 15° to 20°.) The lower of these two stars is Spica in the large constellation Virgo the Maiden. The higher star is Arcturus, in the constellation Bootes the Herdsman.

Arcturus appears orangish white and shines at magnitude –0.04, making it the fourth-brightest star in the sky. Spica is blue-white and shines more faintly than Arcturus, at magnitude 1.0. At a distance of 280 light-years, Spica is quite far away to appear so bright. It is luminous and massive — a spendthrift due to run out of thermonuclear fuel in only about 50 million years. That's in contrast to our Sun's anticipated life-span of about 10 billion years.

Halfway between Leo and Bootes lies Coma Berenices, or Berenice's Hair. It's harder to see than the constellations mentioned so far, but a conspicuous group of faint naked-eye stars makes it worth the effort if you have a dark sky. The direction to the north pole of our Galaxy lies within the borders of this constellation. Contrast this direction to the location of the hazy starlit band now ascending in the east and you can get a sense of the galactic plane in three dimensions.

North of Coma Berenices and tucked under the handle of the Big Dipper lies Canes Venatici, the Hunting Dogs. Its brightest star is Cor Caroli, a 3rd-magnitude star thought to be named for Charles II of England.

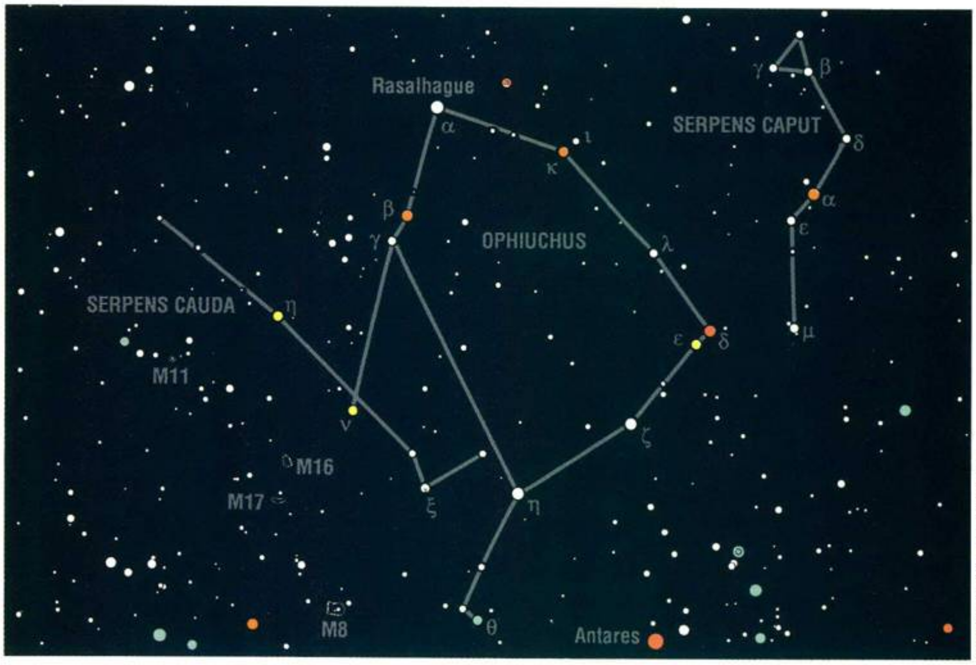
On the other side of Bootes from Canes Venatici and nearly overhead on June evenings is Corona Borealis the Northern Crown. It's easy to spot from a dark site, a compact grouping distinctly shaped like a semicircle. Its brightest star is Alphecca, which shines at magnitude 2.2 from an estimated distance of 75 light-years.

As Earth spins beneath the sky, these springtime stars sink out of view below the western horizon. Meanwhile, the company of stars in the east ascends to dominate the summer night. By 11 p.m. in mid-June (and earlier in July and August), three stars dominate the view to the east. These are Vega, the highest and brightest of the three, Deneb to Vega's north, and Altair to Vega's south. Known together as the Summer Triangle, they make convenient jumping-off points for many of the constellations of summer.

High in the east and about one handspan above Vega on June evenings lies Hercules the Hero. It contains an asterism called the Keystone, a trapezoidal pattern in the center of the constellation that represents the body of the legendary strongman. Conveniently situated within the Keystone is a famous globular star cluster, thirteenth on a list of objects that could be mistaken for comets, compiled by the 18th-century French comet-hunter Charles Messier. M13 contains several hundred thousand of the Galaxy's most ancient stars. This spherical collection of stars — which calls to mind a dandelion ready to lose its seeds — lies nearly 25,000 light-years away and spans more than 100 light-years. Shining at magnitude 5.9, it is barely visible to the naked eye and easy to spot in binoculars. Look about one-third of the way from the star Eta (η) to Zeta (ζ) in the Keystone (see map on page 71).

One star of particular interest lies south of the Keystone. Rasalgethi (Alpha [α] Herculis) is a slightly reddish, 3rd-magnitude star that represents Hercules' head. (The Hero appears upside-down, with his feet above his head, from the Northern Hemisphere.)

The head of Hercules lies next to that of another sky-giant, Ophiuchus the Serpent-Bearer. Rasalhague (Alpha Ophiuchi) is Ophiuchus' brightest star, a white, 2nd-magnitude star located about 5° east of Rasalgethi (about half the span of your clenched fist held at arm's length). Ophiuchus looms large in the southeast on June evenings, but it's not a bright pattern, so you'll need a dark sky to appreciate it. Its name comes from two Greek words meaning "serpent" and "holding."



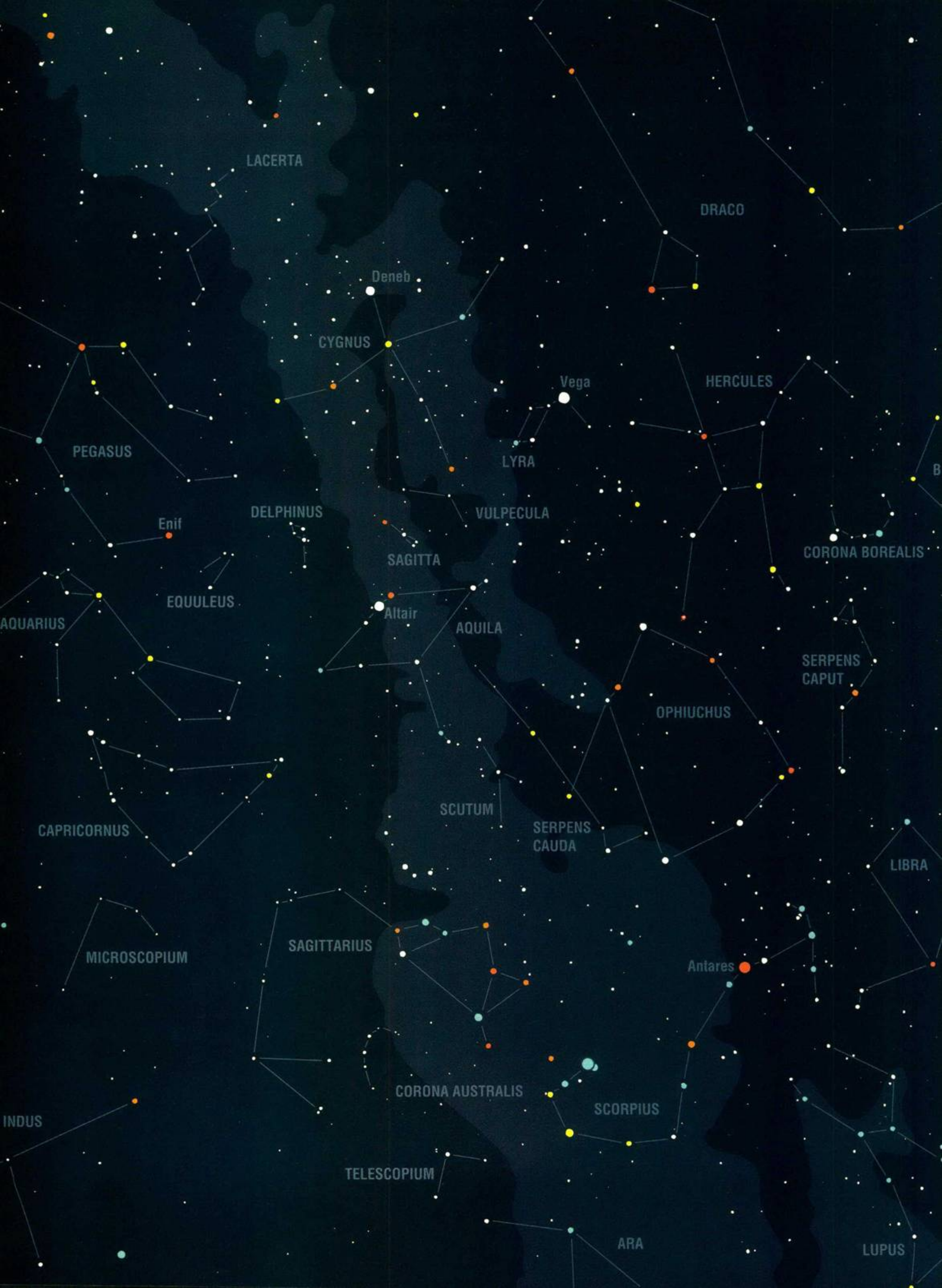
ASTRONOMY: Robert Wegner

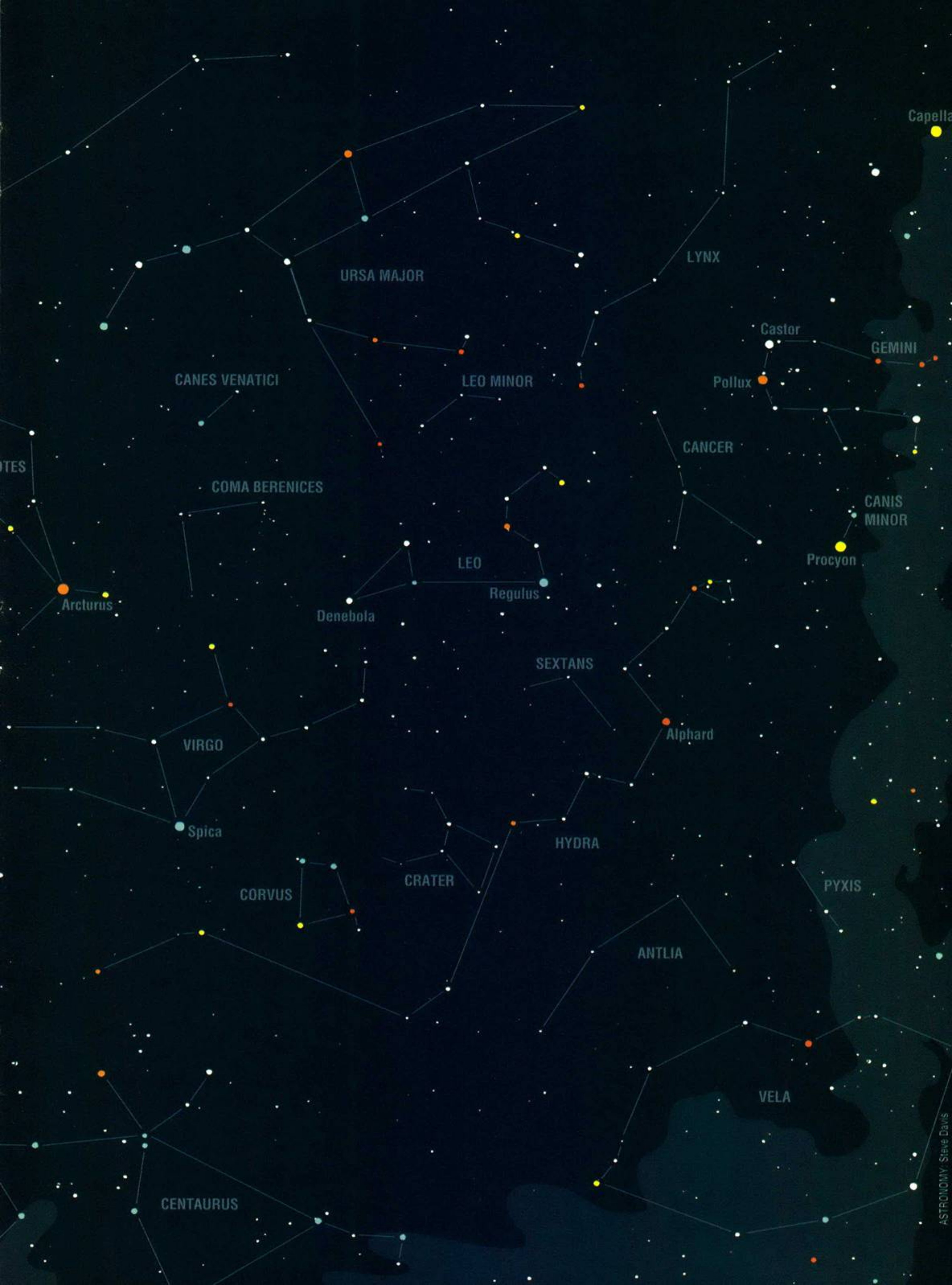
**OPHIUCHUS THE SERPENT-BEARER** grabs hold of the great serpent, which is broken into two parts — Serpens Caput and Serpens Cauda (above). Vega dominates the small but distinct constellation Lyra the Lyre (below).

Stephen Walther

Not surprisingly, the Serpent-Bearer appears to be holding another constellation, Serpens the Serpent. The western part of the serpent's body is the head, Serpens Caput. The eastern part is the tail, Serpens Cauda. The serpent's tail is nearly lost in the rich summer Milky Way north of Scorpius the Scorpion.

And that brings us to the Milky Way! To fully appreciate the Milky Way, you need to get away from the lights of the city and choose a night when the Moon is not in the sky. The


LACERTA
DRACO
Deneb
CYGNUS
Vega
HERCULES
PEGASUS
LYRA
B
DELPHINUS
VULPECULA
Enif
SAGITTA
CORONA BOREALIS
EQUULEUS
AQUARIUS
Altair
AQUILA
SERPENS
CAPUT
OPHIUCHUS
SCUTUM
SERPENS
CAUDA
CAPRICORNUS
LIBRA
SAGITTARIUS
MICROSCOPIUM
Antares
CORONA AUSTRALIS
SCORPIUS
INDUS
TELESCOPIUM
ARA
LUPUS


Capella
LYNX
URSA MAJOR
Castor
GEMINI
CANES VENATICI
LEO MINOR
Pollux
CANCER
TES
COMA BERENICES
CANIS
MINOR
LEO
Procyon
Regulus
Arcturus
Denebola
SEXTANS
VIRGO
Alphard
Spica
HYDRA
PYXIS
CRATER
CORVUS
ANTLIA
VELA
CENTAURUS

ASTRONOMY: Steve Davis

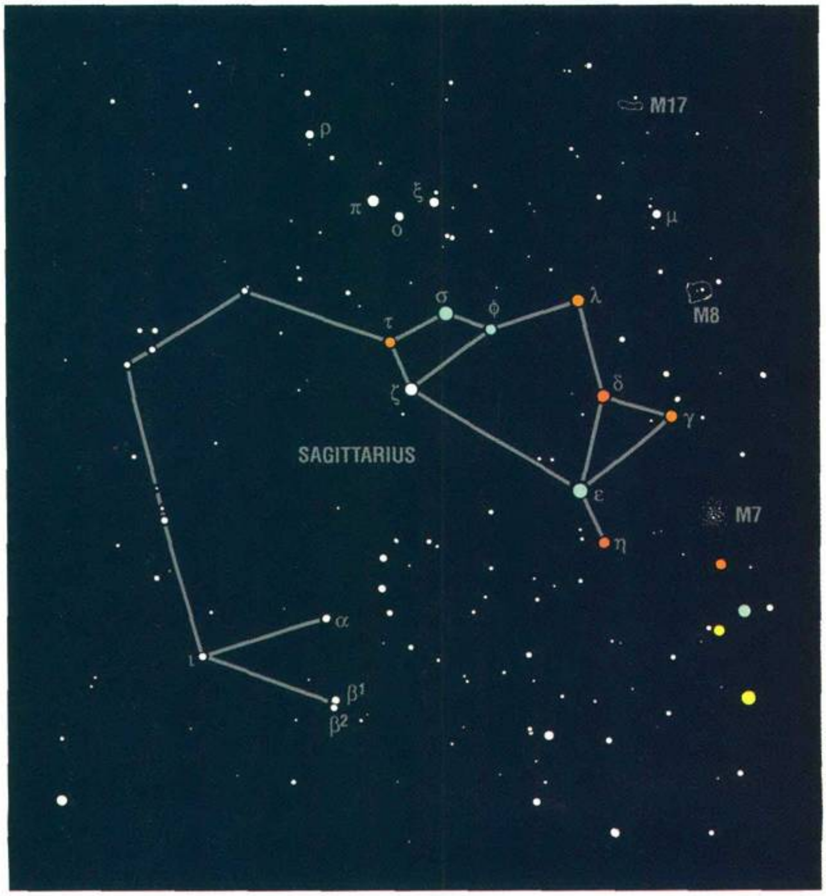
Scorpius region lies nearly due south in late evening and is a good place to start your Milky Way observations.

Orange-red Antares is the brightest star in Scorpius. It lies far enough south that Northern Hemisphere observers never see it very high in the sky. The star represents the Scorpion's heart.

Antares belongs to an association

Stephen Walther

**THE SCORPION'S RED HEART**, Antares, is the focal point of the conspicuous constellation Scorpius (above). Just east of Scorpius lies Sagittarius and its unmistakable Teapot asterism (below).



ASTRONOMY: Robert Wegner

of stars in the Scorpius area. Formed less than 20 million years ago from a single cloud of gas and dust, these stars were born massive and, like Spica, are squandering their fuel. Some of the other bright stars in Scorpius, including Beta (β) and Delta (δ) Scorpii, also belong to this group. Of all the stars in this association, Antares alone has evolved to the red supergiant stage. Its enormous size is the reason it shines more brightly than the others, at magnitude 1.0.

Just west of Antares is another globular star cluster, designated M4. You can spot M4 with the naked eye under ideal conditions and it's easy to pick out with binoculars. The body of the Scorpion makes a graceful curve down toward the southern horizon. You'll find a beautiful star called Shaula, the "Stinger," marking the end of the tail. As seen from the Northern Hemisphere, Shaula (Lambda [λ] Scorpii) sparkles fiercely through the great masses of air near the southern horizon. It has a blue-white color and lies about 330 light-years away.

Now raise your eyes a bit from Shaula. You're looking into a dense, hazy region of the Milky Way, but in a reasonably dark sky you'll easily see two distinct patches of light. These are the open star clusters M6 and M7. Open clusters differ from globular clusters in that they congregate in the plane of the Galaxy and are located closer to us. Turn binoculars on these misty patches of light and watch them break up into remote clusters of glittering stars. At this point, if you want to sweep with your binoculars along the entire hazy band of the Milky Way, do so. The sight of so much "haze" turning into so many stars will take your breath away.

East of Scorpius is a bright, unmistakable asterism, this time in the constellation Sagittarius. It took me a long time to see a Teapot in this pattern, but most people see it easily. Three stars — Epsilon (ε), Delta, and Gamma (γ) Sagittarii — make up the Teapot's spout. As you gaze at the asterism, imagine the hazy Milky Way as clouds of steam rising from the Teapot's spout.

Sagittarius marks the direction to the star-rich center of the Milky Way Galaxy. The exact center lies about 5° northwest of Gamma, but some 30,000 light-years away. We can't peer directly into it, because it's hidden from view by dust and a multitude of stars. When we look in this direction, we're really seeing the next spiral arm of the Galaxy inward from where we are, called the Sagittarius Arm.

Because we're now looking toward the densest part of the Galaxy, there are many wonders in this part of the sky. Aim your binoculars about 6° north of Gamma and you'll find M8, the Lagoon Nebula, a bright compact star cluster surrounded by a cloud of gas and dust. This is an "emission nebula." The hot, young stars here cause the cloud to glow. The word "lagoon" brings mystery to my mind, and this cluster looks very mysterious! You can almost imagine paddling into it. Just north of M8 is M20, the Trifid Nebula. Binoculars show a patch of light; a small telescope reveals the dark lanes that divide this cloud into three lobes. But don't stop there. Scan back to the star that marks the lid of The Teapot, Lambda Sagittarii. Just northeast of there you'll find another large globular cluster, M22.

Now set your binoculars aside. About halfway between Lambda Sagittarii and Altair in the Summer Triangle, notice a large luminous patch in the Milky Way. This is the Scutum Star Cloud, the main claim to fame of tiny Scutum the Shield. This particularly bright region of the Milky Way shines with the combined light of millions of stars.

If you follow the Milky Way north from Scutum, you'll next encounter Aquila the Eagle, the home constellation of Altair. This 1st-magnitude star is flanked on either side by fainter stars. The three, which form an asterism known as the Family of Aquila, appear to be marching arm-in-arm along the Milky Way.

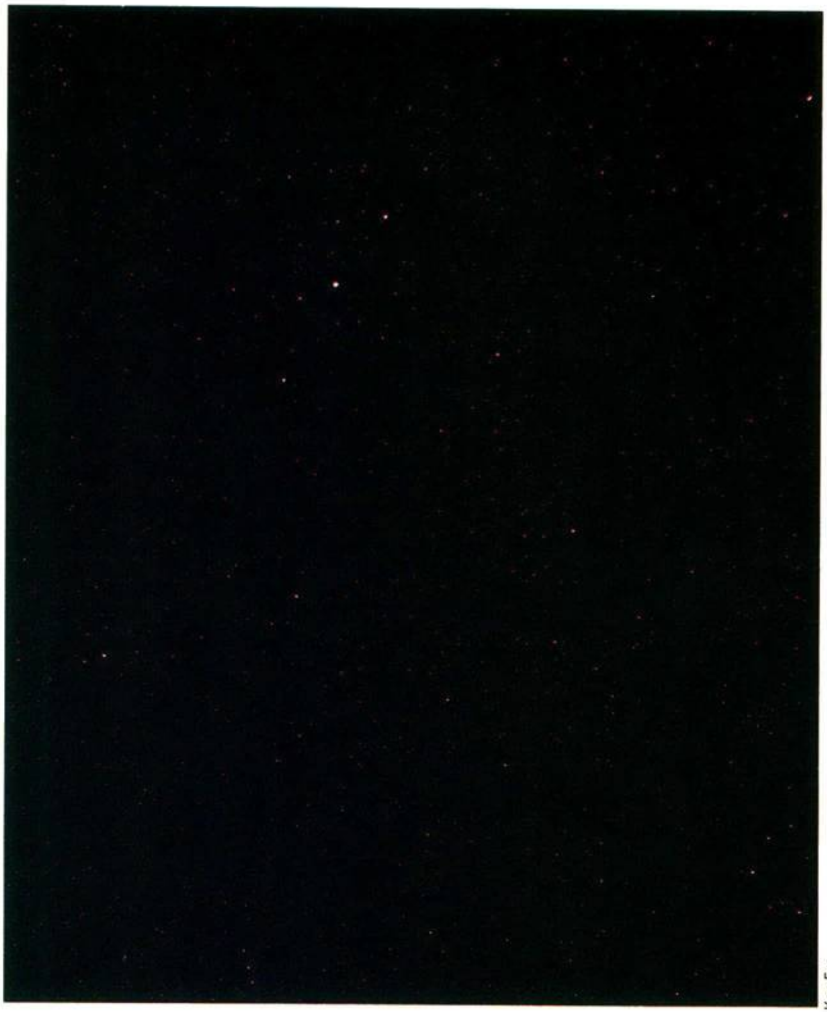
Moving farther north along the Milky Way you come to one of the smallest constellations. Delphinus the Dolphin is compact and, once you find it, easy to see. Look a bit northeast of Altair, along the eastern edge of the starlit trail of the Milky Way. Delphinus consists of four stars in the shape of a tiny diamond. A fifth star set apart from the others calls to mind a real dolphin's leap above the waves.

Twenty degrees (one handspan) northwest of Delphinus is a star that at first can appear inconspicuous in the midst of the Milky Way. It is Albireo, a wide double star in the constellation Cygnus the Swan. You can glimpse the duplicity of this star with binoculars. It's a very pretty telescopic sight, with one component blue and the other gold.

Albireo becomes easy to see once you've traced all of the constellation Cygnus. The constellation of the Swan contains a large asterism called the Northern Cross. In fact, the Cross and Swan are pretty much interchangeable in the minds of many stargazers. Albireo, at the base of the Cross, marks the Swan's head. The crossbar marks the Swan's wings.

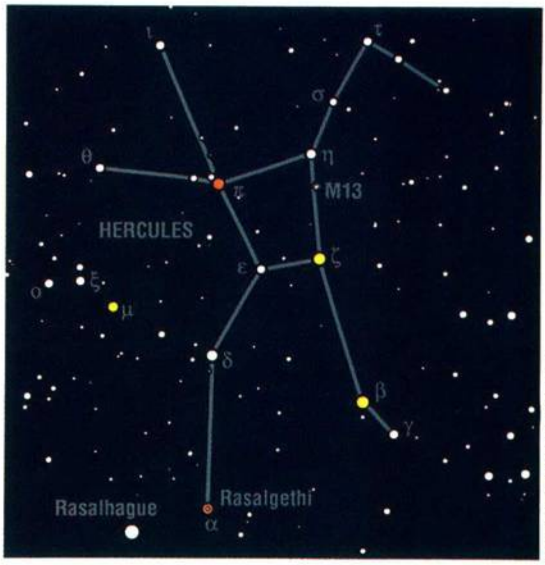
The head of the Cross and tail of the Swan are marked by Deneb, the second of our Summer Triangle stars. This whitish supergiant lies over 1,600 light-years away and shines at magnitude 1.3, making it the most distant of all the bright stars. If it were as near as the Sun's nearest neighbor, Alpha Centauri, which is only four light-years away from us, it would shine as brightly as the Full Moon! The region around Deneb is wonderful for scanning with binoculars. Just 3° east of the star is the famed North America Nebula (NGC 7000).

With the naked eye, be sure to look for the Cygnus Star Cloud, located between Gamma Cygni (the center of the Cross) and Albireo. Here you are gazing at countless stars in the Sagittarius Arm of the Galaxy from a distance of about 7,000 light-years. Finally, look for the Great Rift in the Milky Way. The starlit trail seems to divide in Cygnus, but the dark lanes are really clouds of obscuring dust.



Ken Fye

**THE EAGLE SOARS NORTH** in this photo of Aquila the Eagle. The brightest star is Altair, which forms one-third of the Summer Triangle asterism (above). Hercules the Hero boasts the bright globular cluster M13 (below).



ASTRONOMY: Robert Wegner

Now we return to the brightest star in the summer sky, Vega. This brilliant white star shines at magnitude 0.03 and nearly overwhelms the other stars in its constellation, Lyra the Lyre. Still, you can't mistake Lyra's compact pattern: a parallelogram attached to a triangle.

Besides Vega, there is one other star in Lyra worth noting. Epsilon Lyrae — the outer star in the triangle pattern — is a quadruple star system. The primary pair can be "split" in binoculars, and each of these two stars turns out to be double when seen through a small telescope. Hence Epsilon Lyrae has the nickname of "the double-double."

Lyra is the last stop on our tour of the summer sky. But don't view it as the end of your exploration. Return to the sky often this summer. Get to know the bright stars and constellations well. Before many months pass, they'll slide into the Sun's glare to make way for stars of another season. But rest assured that these bright lights of summer will return on schedule next year. By that time, they'll be old friends! ☐

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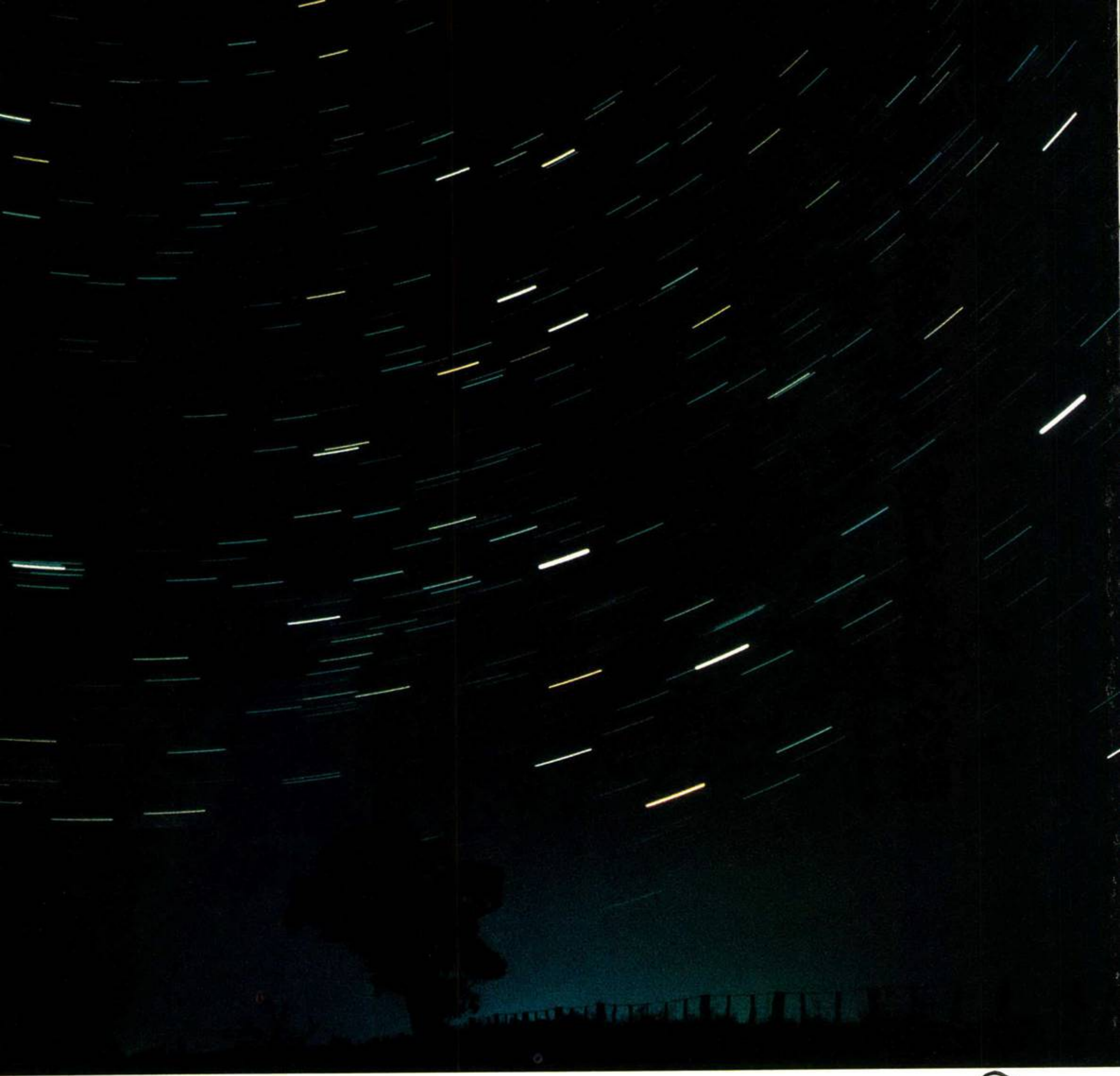
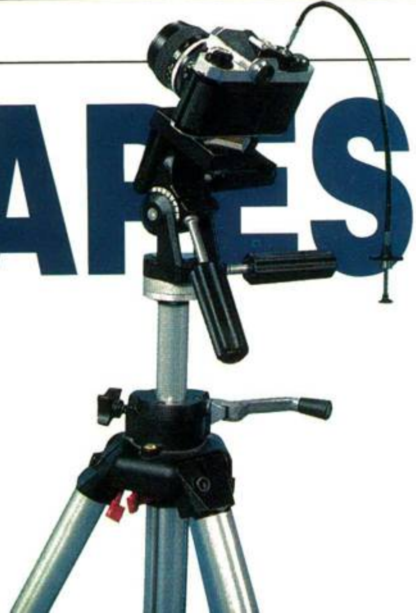
*Deborah Byrd's Eye on the Sky column appears every month in ASTRONOMY magazine.*



ASTROPHOTOGRAPHY BASICS

# NIGHTSCAPES



Create stunning night-sky photos with no more than a camera, a tripod, and a little imagination.

by Robert Bunge

**COMBINE EARTH AND STARS** to produce dramatic nightscapes. All you need is a camera on a tripod. For the photo above, Chris Dunmill used a 50mm lens at f/2.8 and a 10-minute exposure on Fujichrome 400 film. Taken from Australia, this nightscape shows stars circling the South Celestial Pole.

For many amateur astronomers, the word "astrophotography" conjures up visions of expensive equipment, hours of trial-and-error attempts, and long sessions at the telescope glued to a guiding eyepiece. But you can capture dramatic photos of the night sky without elaborate equipment. All you need is the photo gear you likely already own.

What I am referring to is "nightscape" astrophotography, photographs that combine an earthly landscape with the night sky. Including trees, houses, or recognizable landmarks in the frame provides a familiar setting for the celestial objects. A person in the foreground, perhaps looking through a telescope, places a human presence in the image, allowing the astrophoto to tell a story.

Nightscape photography is technically simple — it requires only a tripod, some film, sometimes a flash unit, and a camera with a "Bulb" (B) or "Time" (T) shutter-speed setting. It also requires a touch of creativity. Your choice of a foreground and the lighting for that foreground can make the difference between a ho-hum shot and a great photograph.

### Exposure Times

Nightscape photos divide into two types: those that require short exposures (under 30 seconds) and those that require long exposures (one minute to an hour or more).

Exposures under 30 seconds are short enough to keep the stars looking more or less like dots. With exposures of a minute or more, stars trail into arcs because of the apparent motion of the sky. Both effects produce some interesting photos.

For example, attach your camera to a tripod, point it toward the North Star (or Sigma Octantis for Southern Hemisphere readers), set the lens aperture to f/2.8 or f/4, then open the shutter for fifteen to twenty minutes. If your sky is very dark, an exposure of two hours or more is even better. The result will be a photograph of circular star trails revolving about the celestial pole. By pointing your camera in other directions, you can capture portraits of rising or setting constellations.

If you are shooting star trails from a light-polluted suburban area, take the longest exposure you can without fogging the background sky. You'll need to take some test rolls to determine how long an exposure you can use from your site.

To avoid trailed stars, keep exposures under 30 seconds, though the exact limit depends on where in the sky you are pointed and what lens you are using. (See the table on page 74 for details.) This will allow you to capture constellations much as your eye sees them. In this case, open up the lens to f/2.8 or f/2.

Short exposures (1 to 10 seconds at f/2.8 or f/4) are also all you need to record conjunctions of the Moon and planets in a twilight sky. For twilight shots, you can use the camera's built-in light meter readings as a guide. But don't rely on the meter readings alone. Shoot a series of photos over a range of shutter speeds — a procedure called bracketing — just to be sure. For example, if the meter says 2 seconds at f/4 is fine, then also shoot exposures at $^1/_2$, 1, 4, and 8 seconds.

### Fast Film or Slow Film?

Nightscape photography doesn't require film any more special than what you can buy at your corner drug store. Nevertheless, selecting the right film is an important choice. One of the most common mistakes beginners make is always buying the fastest — the highest ISO number — film available.

For star trail shots, especially from moderately light-polluted sites, lengthy exposures and fast films don't mix. The glow of city lights will quickly fog ultra-fast film and turn the normally black sky into ghastly shades of orange or green.

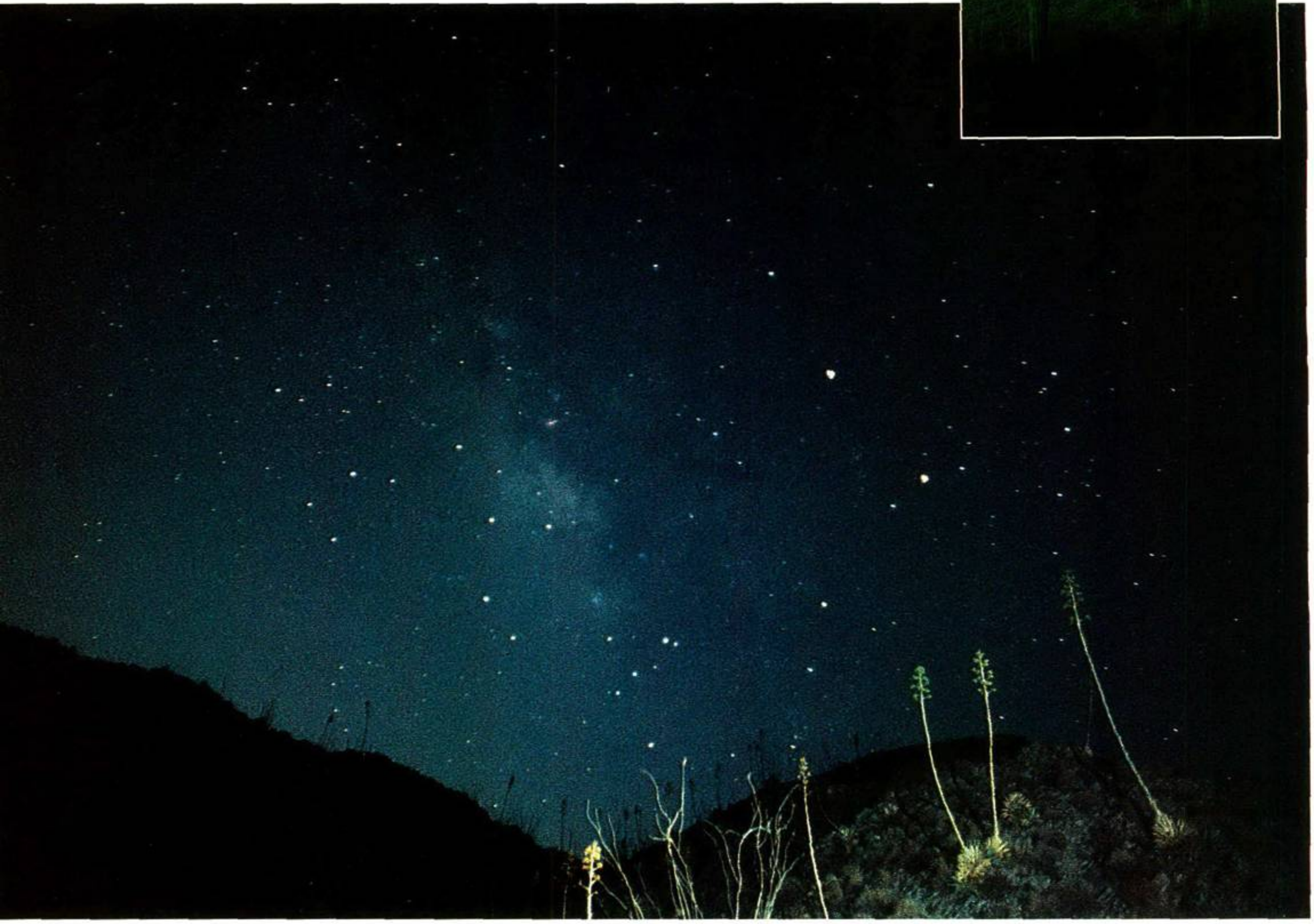
To avoid skyglow during long exposures, use a film with a moderate speed, somewhere from ISO 100 to 400. Some of the better films are Kodak's Ektachrome 100X, Fujichrome 100, and Kodachrome 200, and, for extra recording power, Fujichrome 400 or Scotchchrome 400. These films provide outstanding color reproduction and fine grain for their speed.

For shots of the Moon or planets in twilight, you can turn to slower films such as Fujichrome 50, Ektachrome 64, or Kodachrome 64.

For my nightscape photography, I prefer slide film. With prints, you have to depend on the automatic machine at the local photo lab to select the proper density and color of the print. The result might not be very pleasing Because slide film is inherently more contrasty than print film, it provides brighter, more vivid colors.

However, many astrophotographers like to use print films. A primary attraction of these "color negative" films is the availability of ultra-high speed emulsions like Konica 3200. ISO 1000 to 3200 films are great for capturing the faintest stars

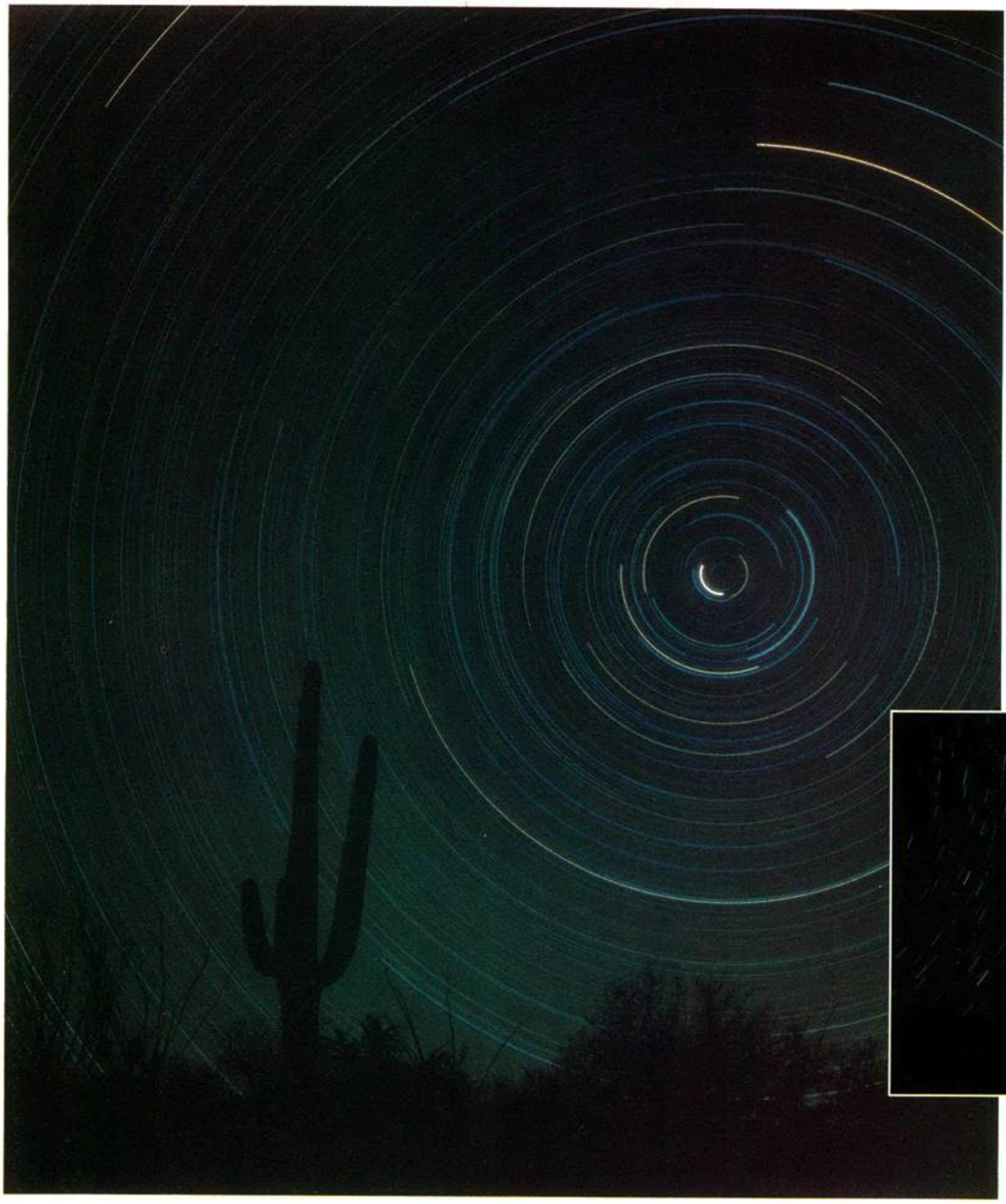
**SHORT EXPOSURES AND FAST FILM** keep stars looking like points. In Jerry Schad's 45-second exposure below, a combination of a 24mm lens at f/1.4 and ISO 1600 film recorded the stars and the summer Milky Way over California's Anza-Borrega Desert. A flash lit up the foreground. For his Arizona nightscape at right, Allan Morton used a 35mm lens at f/2 for 20 seconds on Ektachrome 400 film. Nearby mercury-vapor street light illuminated the cacti.



## AVOIDING STAR TRAILS

| Lens | Celes. Equator | Near 45° Declination | Near Celes. Poles |
|---|---|---|---|
| 28mm | 25 sec. | 40 sec. | 90 sec. |
| 50mm | 12 sec. | 20 sec. | 45 sec. |
| 135mm | 5 sec. | 7 sec. | 16 sec. |

To keep stars looking like points, use exposures no longer than these. Since stars move through shorter arcs near the celestial pole, exposures can be longer when you aim to that part of the sky.



**HAPPY TRAILS** result when you leave the shutter open for several minutes. Brian Kimball used a 4x5 view camera with a 135mm lens at f/8 and a 7.5-hour exposure on Fujichrome 50 film for an ultra-sharp photo of circumpolar star trails (left). Jerry Schad captured stars rising behind a forestry lookout tower (below). He used a 35mm lens at f/2 and a 15-minute exposure on Ektachrome P800/1600 processed at ISO 1600.

possible in exposure times short enough to avoid trailing. Using Konica 3200 from a dark site, for example, you can capture Milky Way star clouds, even with exposures as short as 30 seconds at f/2.

### Wide-angle or Telephoto?

The majority of 35mm-format cameras come with a 50mm lens as standard. For most nightscape astrophotography, this lens will do just fine. Sometimes, though, a 50mm lens doesn't show enough of the sky or foreground. You may want to switch to a wide-angle lens such as a 35mm, 28mm, or even 20mm.

Wide-angle lenses are good for star trails and some Moon and planet shots. But with focal lengths less than 50mm, the image of the Moon isn't large enough to show the Moon's phase or size.

Telephoto lenses, ones with focal lengths of 100mm or longer, are great for other types of astrophotography but have a limited use for nightscapes — their field of view is too narrow. However, telephotos can be good for shots of the Moon rising over a distant landscape or a tight grouping of planets.

### Shedding Light on the Subject

Astronomical subjects come with their lighting already provided. There is little you can do to affect the type or amount of light from the Moon, planets, or stars. But you do have some control over the foreground.

Try a number of lighting sources to accent the foreground. On rare occasions, you can use streetlights to advantage. But in most cases streetlights are not an attractive choice. Just as they do to the sky, they will make the foreground of the photo appear green or orange.

A better light source is the Moon. Because its light is reflected sunlight, it has a natural color balance. The amount of moonlight falling on the ground is also faint enough that it will take fairly long exposures to

**A NORTHERN EXPOSURE** taken by Jim Egger captures the crispness of a winter night. Taken from Alaska, Egger's winter sky portrait of Orion is a 1-minute exposure on Fujichrome 400. Moonlight provided the right illumination for the snowy landscape.

**MULTIPLE EXPOSURES** (left) allowed William Sterne to record the Moon and Venus setting over Tulsa. Brian Kimball shot the Moon, Venus, Mars, and Jupiter (below) in June 1991, using a 50mm lens at f/2.8, at $^1/_4$-second on Kodachrome 64.

record it, long enough to allow you to pick up stars as well. Use the Moon when it is less than 45 degrees high in the sky, and place the Moon behind the camera just as you would the Sun during the daytime.

You needn't depend on nature or a conveniently placed streetlight to provide your landscape illumination. During exposures of several seconds, you can "paint" an object in the foreground with the light from a bright flashlight. Alternatively, the red lighting used by amateurs and found inside observatories may be enough for shots of telescopes against a starry background.

A more controlled source of lighting is an electronic flash unit. You can adjust its location and the amount and color of the light it produces. For intricate shots, you can even add multiple flashes, either by firing the same flash several times from different spots while the shutter is open, or by using several slaved flash units.

When using a flash, first choose the exposure needed to record the sky. Then estimate the distance from the camera to the foreground subject. Use the scale provided on the flash to choose the power setting that will provide the right amount of light for the camera-to-subject distance and for the f/stop required by the sky exposure. Unless you are trying to freeze a foreground motion, it doesn't matter when during the exposure you set off the flash.

By being creative with the composition and lighting, you can create award-winning astrophotos that combine the familiar with the unearthly. And all without expensive telescopes, elaborate accessories, or special films. The secret to good nightscapes lies not in the equipment but in your own imagination. ☐

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*Robert Bunge is an active deep-sky observer and telescope builder who lives in Laurel, Maryland.*

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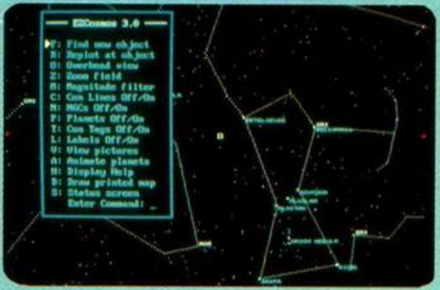

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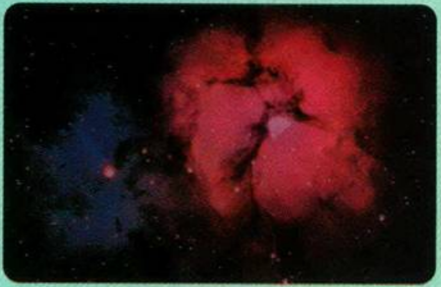

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3 PART SERIES

PART 3

# Building Owl Observatory

In this final installment, you will learn how to build the roof and add the finishing touches to this backyard observatory.

Story and photos by Jim Krick

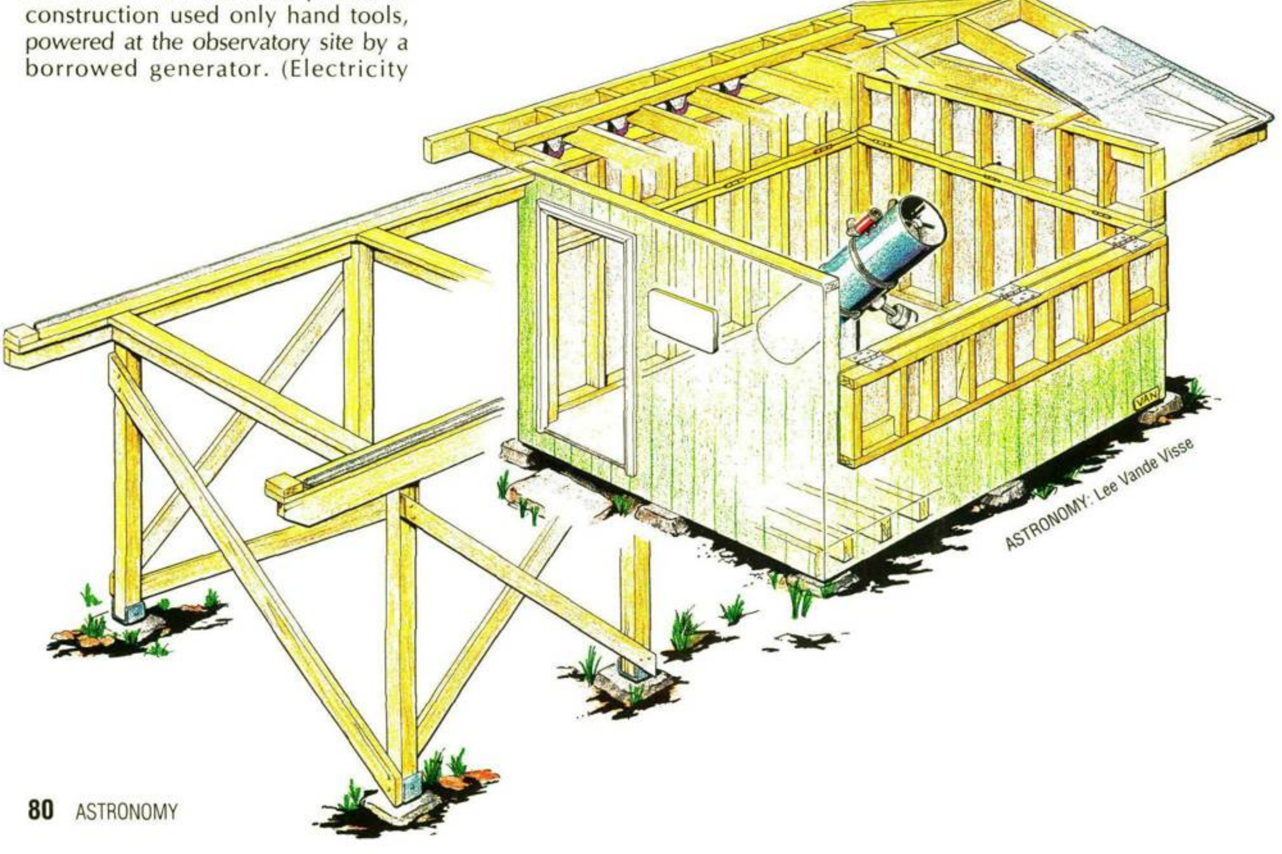
Owl Observatory is a 10'x10' building located about twenty-five miles east of Great Falls, Montana. I built the observatory to pursue astrophotography in comfort during Montana winters. Its elevated wooden floor prevents animals from nesting under the building and is warmer than concrete during the cold winter months. The roof rolls off and the upper two feet of three walls fold down to give me complete access to the sky for astrophotography. Yet the four-foot rigid walls shield me and my telescope from the wind while I'm observing.

Part one of this series described how I built the telescope pier and building foundation and part two described the construction of the floor, walls, and the bottom timber of the roll-off roof rails. All phases of construction used only hand tools, powered at the observatory site by a borrowed generator. (Electricity wasn't provided by the local power company until I had almost finished the observatory.) And the total cost of the observatory was only $1,500. In this last article of the series, I'll tell you how to finish the roll-off roof rails, prefabricate and install the roof, and add some finishing touches. Let's start with completing the siding.

### Finishing the Siding

In part two, I described the installation of the $^{3}/_{8}$" hardboard siding over the sheathing on the rigid sections of the walls. However, the fold-down wall sections had only oriented strand board (OSB) sheathing applied. First, I installed scrap pieces of OSB sheathing to the corner studs of the east and west fold-down wall sections, overlapping the edge with the previously applied sheathing to form a weatherproof corner. I cut 2'-long, 4'-wide sections of the siding to cover the fold-down wall sections, matching the vertical pattern of the siding on the rigid walls. Then I covered the ends of the east and west fold-down wall sections with siding, again overlapping the edges.

The corners on the north wall also needed scrap pieces of OSB sheathing applied to the corner studs so siding could be installed flush with that of the fold-down wall sections. I used $1^{1}/_{2}$" screws to fasten the sheathing



ASTRONOMY: Lee Vande Visse

and siding. (You also can use 6d nails.) With the siding in place, the roll-off roof rails can be installed with the proper overhang.

### Finishing the Roll-off Roof Rails

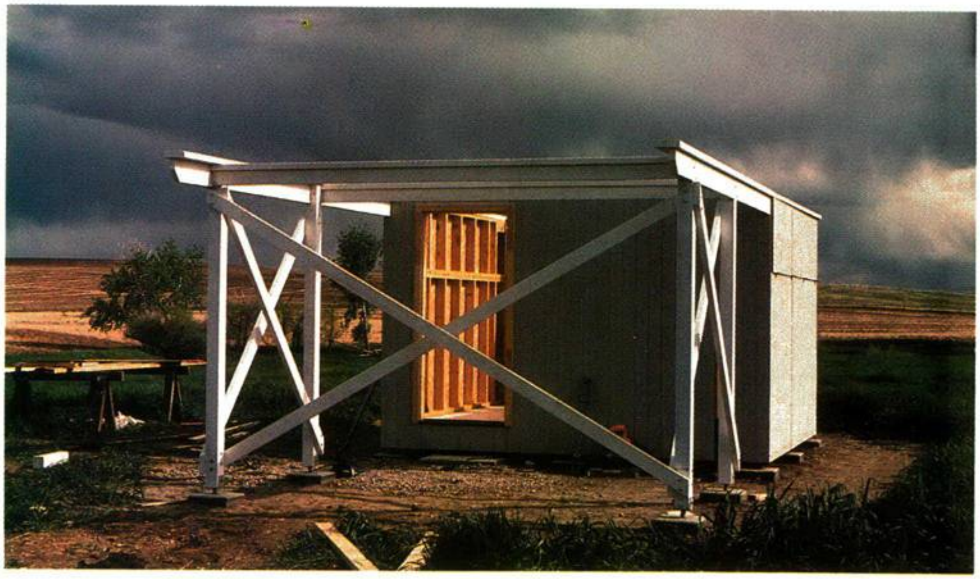
The roof rolls toward the north from its closed position on top of the observatory walls to its open position on 2x6 rails elevated by two pairs of posts. These rails have two sections on each side: a 9'-9$^1/_2$" section attached to the top of the east and west fold-down walls and a 13'-1" section that attaches to the 13' bottom rail timbers installed in part two of the construction. I used strong softwood (wood species group II) for these rails so the casters supporting the roof assembly won't wear into the wood. A very hard wood like oak (species group I) isn't necessary, but you should avoid soft woods like pine or cedar (species group IV). Ask at your lumberyard which locally available variety of wood best suits the rail. The growth rings of the wood should be placed down (that is, the crown of the board is on top) to minimize warpage.

Install the fold-down wall sections of the rail first. I overlapped the 2x6s so about $^3/_4$" hangs over the siding and at the ends. This leaves about $^1/_2$" overhanging the inside of the wall. The slight asymmetry allows for a flush fit with the $^3/_4$"-thick corner caps installed later. Be sure that the 2x6 won't prevent the top section of the wall from folding down. Then attach the rail to the wall with 3" screws placed every 12 to 16 inches.

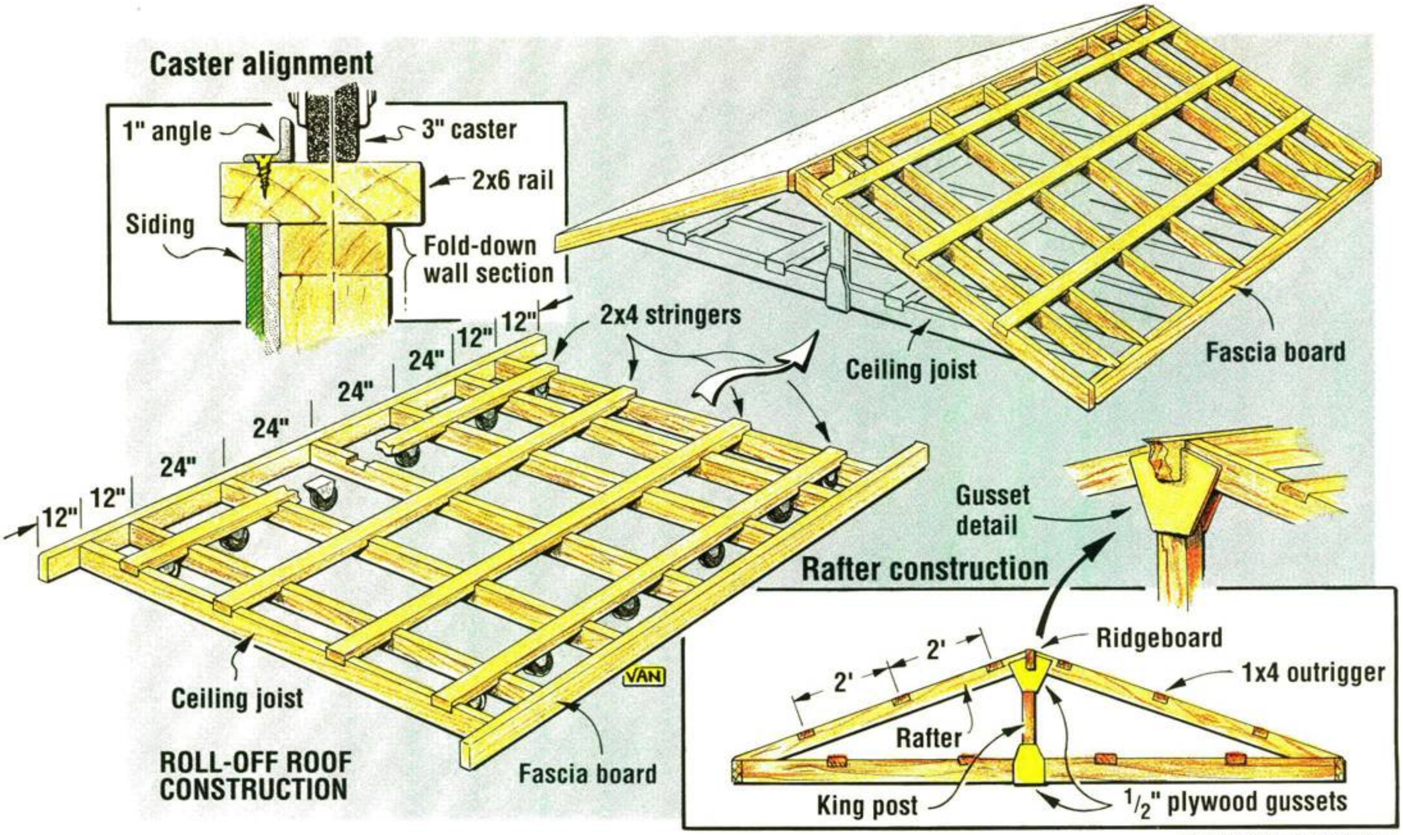
The remaining rails go on the bottom rail timbers on the north side of the building. Attach the rails so they line up with the rails on the fold-down wall sections. About 1" of the rail should extend over the north end of the bottom timber. Use 3" screws every 12 to 16 inches to fasten the rail but be careful that the screw doesn't split the side of the bottom rail. I trimmed out the rest of the wall sections with 9'-3$^1/_2$" pieces of 2x6 so the tops of the wall will be level. The north and south walls repeat the $^3/_4$" overhang on the east and west walls. The south wall trim required that I remove a $^1/_2$" x 5$^1/_2$" section of the south ends of the rails on the east and west walls to accommodate the 2x6 trim.

Next I installed two more posts to support the rails and built cross bracing for all four posts. First I braced the two posts already in place. Carriage bolts ($^1/_4$-20, 5$^1/_2$" long) secure all of the braces. A 9'-9"-long 2x4 acts as a collar tie across the top of the posts on their outside (see photo at top). The cross braces are 12' lengths of 2x4, cut to length after being bolted in place. I put one brace on the inside of the posts and then removed the temporary post bracing installed in part two. A second brace added on the outside of the posts further strengthens the posts. Staggering the braces on the inside and outside prevents having to cut joints for the braces.

The second set of 4x4 posts are 6'-7$^7/_8$" long and have a 1$^1/_2$"-deep, 5$^1/_2$"-long rabbet cut in the top to hold the bottom rail. Bolt the posts in place with a $^1/_2$" bolt through the post bracket in the footing and 4"-long, $^1/_4$x20 bolts to the rails. Then you can install the two sets of side braces. These braces are cut from 8' lengths of 2x4. Two of the braces can be cut to length after being bolted in place, but two need to have the bottom end cut before they are installed. The inside and outside braces should go in the same direction as their counterparts on the first set of posts. This keeps two braces from ending on the same inside portion of a post, resulting in a weak connection. A 2x4 collar tie (9'-9" long) across the top of the second set of posts finishes the bracing.



**THE ROOF ROLLS ALONG** rails supported by the fold-down wall sections and 4x4 posts (top). Cross bracing made from 2x4s bolted in place keeps the posts plumb. Note that the outer braces go from the top of the left post to the bottom of the right post. The roof was prefabricated in my garage during the winter (above) and later reassembled at the observatory site.



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### Building the Roof

As soon as I finished the rails, the roof could go up, because I assembled it in my garage during the winter after I prefabricated the observatory walls. The garage was warm and I could cut the rafters more uniformly than I could at the observatory site. A miter saw makes cutting the ends of the roof rafters easier, but it isn't necessary. All the parts were cut, screw holes predrilled, and the pieces assembled to test their fit. Then I disassembled the roof for transportation to the observatory. I labeled and numbered parts once they were in place to ensure that they would be reassembled in the same positions.

Several considerations went into the roof design. The roof pitch must shed snow in the winter. The roof must also be strong enough to resist strong winds and heavy accumulations of snow. And it must be light enough for one person to roll off and on during an observing session.

The final design of the roof is simple (see the illustration above). The roof is gabled, with the gable ends overhanging the north and south sides of the building by one foot. The eaves on the east and west sides also extend one foot. A rolling frame of 2x4s acts as the ceiling joists and supports for twelve 3"-diameter, heavy-duty, fixed-wheel casters. Fixed-wheel casters keep the wheels pointing along the rails. With six casters on each side, two or three wheels are always in contact with each rail, so pushing the roof along the rails is easy. King-post supported rafters make the 2x4 structure strong enough to resist wind and snow loads. And corrugated steel roofing, instead of plywood decking covered with shingles, makes the roof light enough that one person can push it. I estimate that my finished roof weighs only about 100 pounds.

The seven cross members, or ceiling joists, of the rolling frame are 12' lengths of 2x4. (Orient the 3½" side of the boards vertically.) I spaced the joists 2' apart except at the gable ends, where the spacing is 1'. Four 2x4 stringers that are 10' long hold the joists in place. The stringers fit in ¾" dadoes cut in the ceiling joists. The stringers themselves are not jointed. I first screwed the stringers in place with 3" screws and then bolted the joists and stringers together with 4½"-long, ¼x20 carriage bolts. The bolts hold the frame together while the screws keep the joints from twisting. Fascia boards, made from 12' lengths of 2x4, cap the ends of the joists.

I selected a 4/12 slope for my roof because of the potential snow load. This slope means that the peak of the roof stands 24" higher than the ceiling joists. Given a 6' rafter run, which is the distance from the edge of the fascia board to the centerline of the roof, the lengths of the rafters must be slightly more than 6'-3".

The rafters need to be supported in two directions. In the horizontal direction, a 2x4 ridgeboard provides a nailing surface for the rafters and keeps them plumb. King posts help support the rafters vertically to prevent the roof from collapsing. The king posts strengthen the roof so much that you can use 2x4s instead of 2x6s for the rafters. (If you don't employ king posts in your trusses, use 2x6s for the rafters; 2x4s are still sufficient for the ceiling joists in this case.) For my 4/12-sloped roof, I used seven king posts that were 1'-8½" long.

To build the roof on the rolling frame, I temporarily supported the 12'-long ridgeboard with two king posts on the ends. This allowed me to test fit one rafter that I then could use as a template to cut the other rafters. The rafter tail, which is the end by the fascia board, forms an angle of roughly 18.5 degrees while the ridge end has an angle of about 71.5 degrees. (A rafter square will aid in marking your rafter cuts, but you also can mark the cuts while holding the rafter in place.) I avoided a complicated bird's-mouth joint. Instead I used a simple butt joint of the rafter to the ceiling joist.

After cutting all 18 rafters to length, I notched them for three 1x4 outriggers. *The outriggers* keep the rafters from twisting and provide a surface for attaching the corrugated roofing. I marked and cut one rafter to use as a template to mark the outrigger positions on the other rafters. The first outrigger lies about 1' from the ridge end of the rafter. (Be sure it will clear the gussets described below.) Space the other two outriggers about 2' apart.

When all the rafters were cut, I assembled seven truss assemblies of one king post and two rafters. There are only seven trusses because the end rafters form a gable and do not have king posts supporting them. I also cut out gusset plates from 1/2" plywood to strengthen the king-post joints. I used four gussets, two at the bottom, where the king post fastens to the ceiling joist, and two at the top, where the king posts, ridgeboard, and rafters join (see the illustration on the opposite page). I used construction adhesive (not glue) and screws to fasten the gussets to the king posts and rafters (but no adhesive at the joints with the ridgeboard and ceiling joists), because the trusses weren't disassembled for carting to the observatory site.

I built the entire roof in my garage, making sure that all joints fit properly. Every screw holding the ridgeboard, rafters, king posts, and outriggers together was fastened, so construction at the observatory would be simply a matter of reassembly. After it was all assembled, I carefully took it apart for transport to the observatory, checking that each part was labeled to ease the roof's later reassembly. Each part then got a coat of exterior-grade primer. Finally I installed the casters on the outer stringers of the rolling frame.

The ceiling joists create six sections — and thus six caster locations — along the outer stringers. Each section is marked by two holes for the 1/4x20 bolt that fastens the stringer to the joists. I installed a caster halfway between each pair of bolt holes. A chalk line snapped along the stringer aided in lining up the casters so they all roll in the same direction. With the casters installed, I trucked the roof parts out to the observatory.

### Installing the Roof

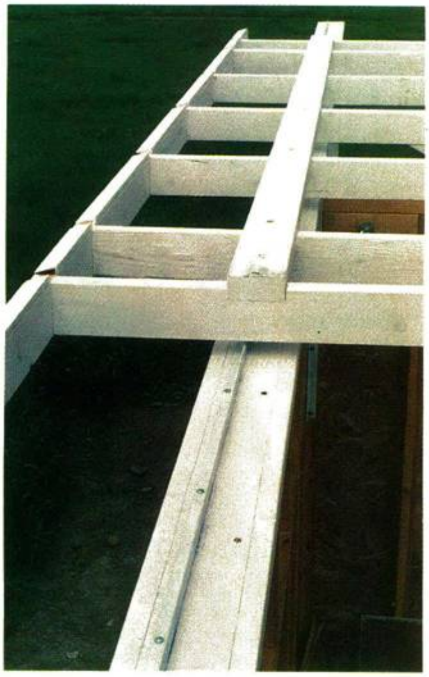
The rolling frame went back together first. I reassembled on the ground all but the inner stringers of the frame — no sense lifting extra weight — then lifted it onto the south end of the rails. The south wall temporarily supported one end of the frame while I lifted it. With the frame in place, I screwed a block made from scrap 2x6 onto the end of each rail to prevent the roof from rolling off the rail. The north blocks were beveled toward the end of the rail to shed water.

Then I snapped a chalk line just outside the casters to mark the location for pieces of 1" angle (see the illustration on the opposite page). Thick aluminum angle is sturdy enough and is maintenance free compared to steel angle. The angle acts as a guide for the casters when the roof is pushed back and forth. Two 9' lengths of angle suffice for the fold-down wall sections, while the other rails require 13' lengths. I fastened the angles with 1 1/2" screws every 12". With the rolling frame constrained to move along the rails, I installed the roof trusses next.

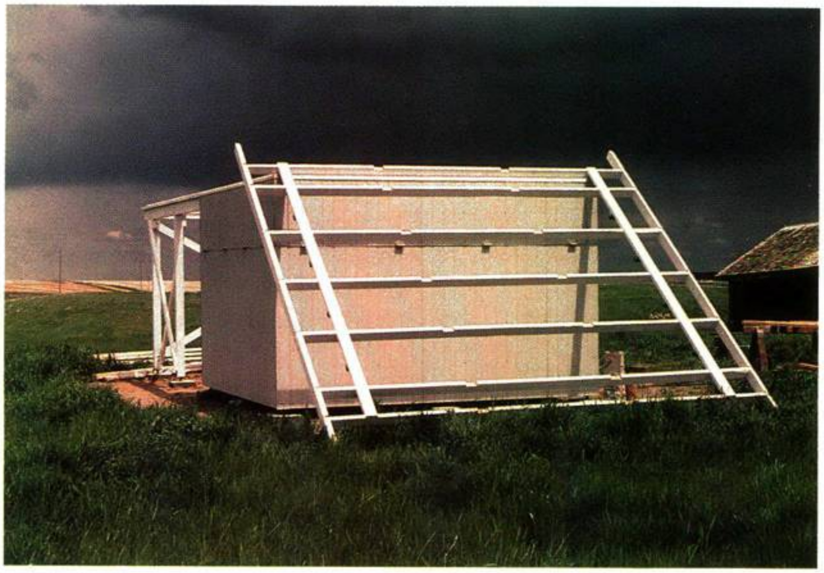
The roof trusses, ridgeboard, and outriggers were merely re-erected according to the labels on each board and truss. After reassembling the roof, I installed hardboard siding on the gable ends and along the eaves, matching the pattern of the siding on the walls below. Use 6d nails or 1 1/2" screws to fasten the siding. A wooden cove or L-shaped piece of thin, flexible metal fastened along the eaves (where they meet the hardwood rail) helps to seal the gap between the roof and building. I added a 1x4 along the bottom edge of the north gable end. This strip helps seal the gap between the roof and wall when the roof is closed. Before installing the corrugated roofing, I covered the fascia board and gable rafters with a drip edge to prevent rain from working its way back into the building.

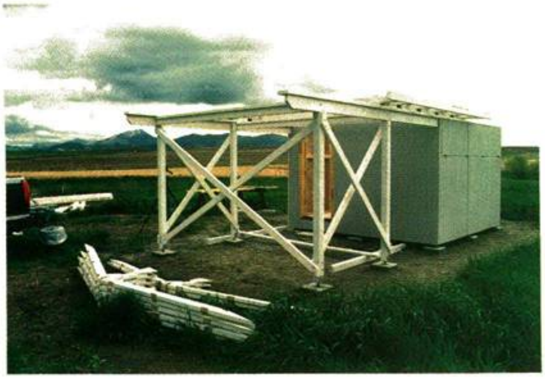
You can choose from a wide variety of roofing materials. Steel and aluminum are the most popular and come in many different corrugation designs and factory applied enamel finishes. I chose white to help reflect sunlight during the day.

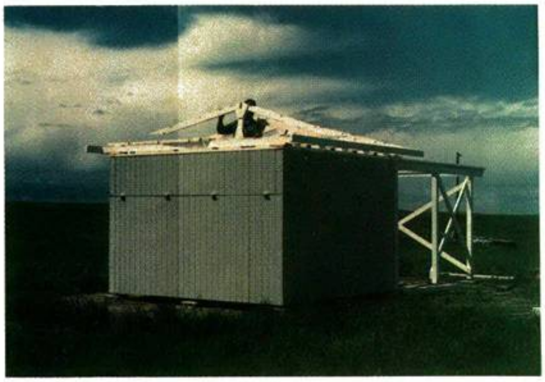
Installing corrugated roofing is easy. Cut the roofing to length with a powered handsaw equipped with a metal cutting blade (typically this is an abrasive wheel). And be sure that you use the proper fasteners for the material you are using. The

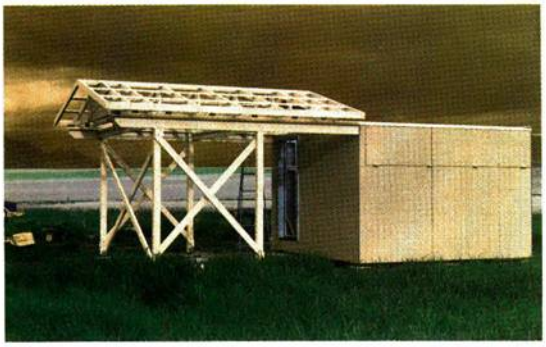


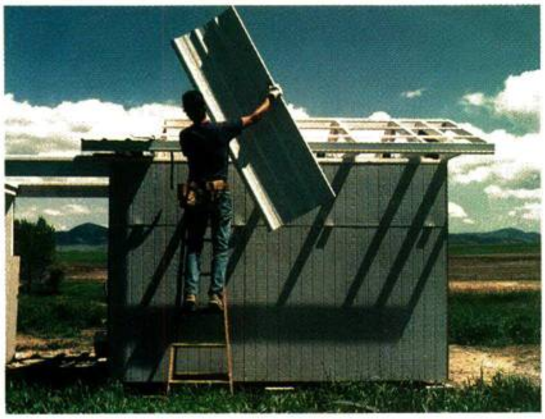
**THE ROLLING FRAME** was reassembled at the observatory on the ground and lifted into position (below). One-inch aluminum angle, screwed every 12 inches along the length of the rails, guides the frame's casters when rolling the roof back and forth (left).











**RAISING THE ROOF** starts with preassembled king-post trusses that are screwed to the joists in the rolling frame and ends with corrugated metal roofing that attaches to three 1x4 stringers (photos from top to bottom).

wrong screws or nails will produce a chemical reaction, weakening the roofing and thereby leading to roof leaks, and panels being torn off by the wind. The screws I used have a neoprene washer near the head, which automatically weatherseals the screw hole.

Although you should follow your roofing manufacturer's instructions, I'll describe how my roofing panels went in. As I placed each piece of roofing, a piece of weatherstripping went between the fascia board and the roofing. Weatherstripping also went between the roofing and the gable end rafters. Some manufacturers also give you an adhesive piece to place between the overlapping sections of roofing. This strip helps seal the gap between the two pieces of roofing.

I placed all the pieces flush with the ridge ends of the rafters and with a 1" overhang at the fascia board. The first piece overhangs the gable rafter edge by about 1" and has a corrugation for strength. I filed the end that hangs over the fascia board to remove any sharp edges or burrs. The next piece overlaps the previous piece at a raised corrugation so rain will travel down the corrugation and not into the building.

Each corrugation got a fastener at each outrigger and at the fascia board. Winds at my observatory often exceed 25 miles per hour, so I wanted each panel fastened securely to the roof supports. The panels I used were 34" wide, so each sheet covered about 30", accounting for the overlap of the corrugations. Your roofing may cover more or less depending on its width and the corrugation pattern. About 4" had to be cut off the length of the last panel to leave a 1" overhang on the gable end. (Make this cut next to a corrugation, if possible.)

Capping the roof took place once all the roof panels were installed. I bought a one-piece roof cap painted the same color as my roofing. It too is preformed for strength. I fastened the cap to the ridgeboard with screws and neoprene washers about every 16". A space may exist under the cap at the gable ends, but mice and birds can't enter the building this way because the roofing extends up to the ridgeboard.

Before starting the finishing details of the observatory, I provided a means of securing the roof. I didn't want someone forcing the roof open and gaining access to the observatory or a strong wind blowing the roof off the building. I tried gate hooks but they didn't work very well. Now I use chain tensioners — called boomers by some people — which are available from many hardware stores. Four large eye bolts in the ceiling joists line up with large screw eyes in the studs in the fold-down wall sections. Hooks in the ends of the tensioners fit in the screw eyes and eye bolts. A turnbuckle and a hinge-and-lever mechanism allow the tensioner to be closed with just the right amount of tension to secure the roof.

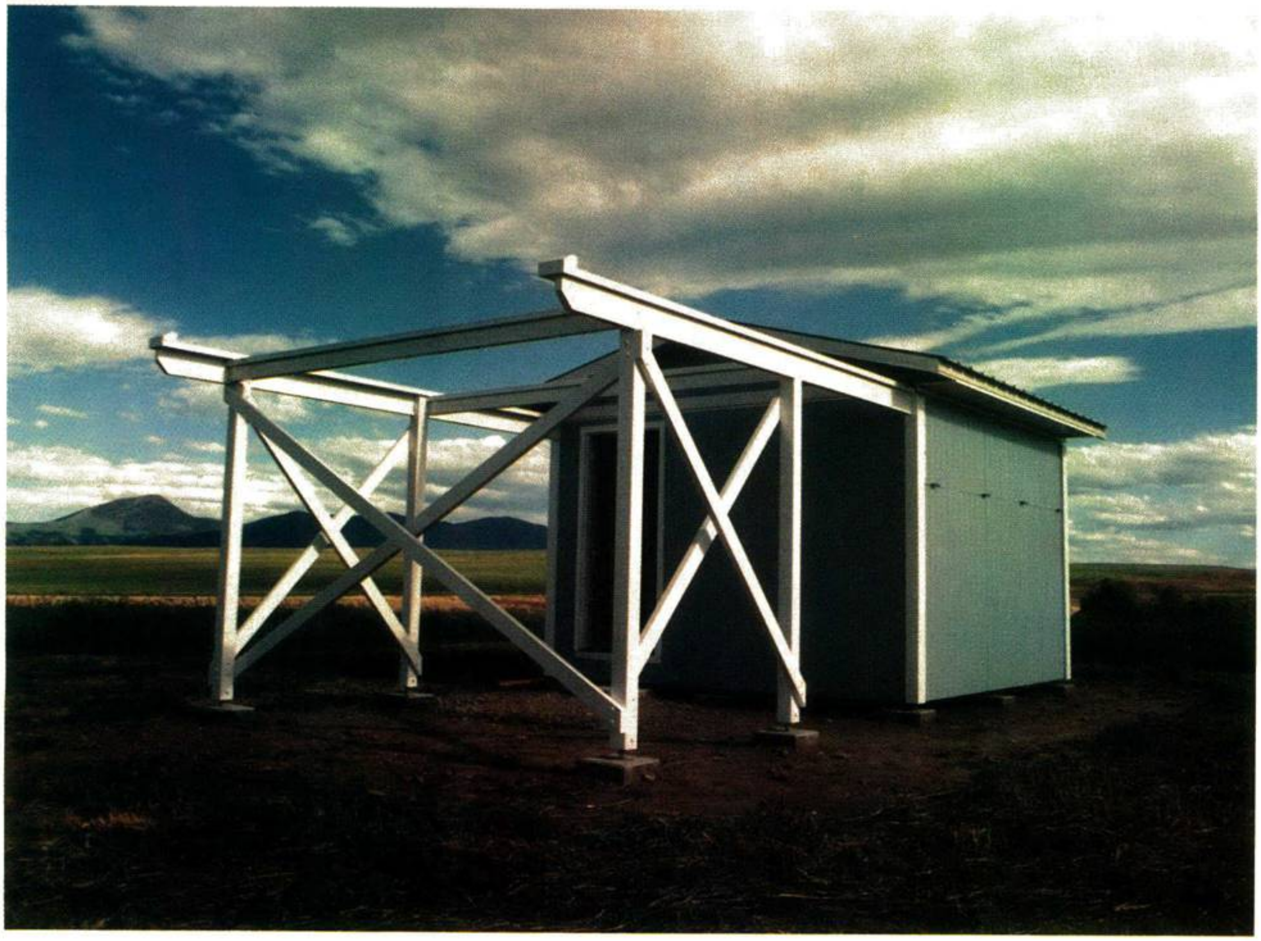
### Finishing Details

With the roof in place, it's time to add the finishing touches. These details include finishing the floor, adding corner caps, and painting the building. I didn't clad the inside of the walls. That's a project I may undertake after I enjoy using the observatory for a while. But you may wish to install the interior wall cladding at this time, using gypsum wallboard (sheetrock), paneling, or wood siding.

Unless you put in a 1"-thick plywood floor at the start, the floor is really a subfloor and you should install a second layer, or underlayment, of plywood or particle board. The actual type of underlayment depends upon the flooring you decide on. If you wish to paint the floor, a good grade (AC) of 1/2"-thick exterior plywood will do. Use an underlayment-graded plywood, if you can find it, because voids between its plies have been filled, preventing shoe heels from punching holes in the floor. Fill all joints with an exteriorrated floor-leveling material prior to painting. Otherwise, the joints will harbor dirt and dust that will eventually find their way to your optics. Outdoor carpeting or tile requires a dense particle board underlayment that is 1/2" to 5/8" thick. Whether you install plywood or particle board, place a bead of construction adhesive between the subfloor and underlayment and screw (2 1/2" long) or nail (10d) the underlayment to the floor joists.

After finishing the floor underlayment, I installed the door threshold and rehung the door. Weatherstripping around the door prevents dust, rain, and snow from blowing into the building. My door didn't have holes predrilled for the door knob and lock, which was fortunate because I had to cut the bottom off the door. The knob would have ended up too low for normal use. I installed the door knob about 36" above the floor.

Trim around the door opening covered any gaps between the door



**THE FINISHED OWL OBSERVATORY** has siding installed in the gable roof ends and along the roof eaves, corner boards made from 2x4s, the door replaced, door trim, and a coat of exterior paint.

frame and siding. I used standard brick molding, but you also could use other milled woodwork for the door trim. Avoid casings with a grooved back, because the hollow could trap water that will eventually rot the woodwork. I used 10d finish nails to attach the trim to the studs in the door frame.

To further prevent rain from penetrating the corners and damaging the siding, I built caps for the four corners of the building. If your strap hinges do not give you sufficient clearance (mine swing the fold-down wall sections 1 1/2" away from the rigid walls), you may wish to forego corner caps or use a thin aluminum cap. The caps could be built from 2x4s, but I used 1x3s and 1x4s. Using a 1x3 on one side of the corner and a 1x4 on the other gives a nice square appearance. The tops of the caps fit flush against the roll-off roof rails. The north wall corners are easy to build because the caps extend the entire height of the wall. The south wall caps are more difficult to make because the east and west walls fold down, requiring a joint in the south corners.

I made the caps for the south corners in two pieces. The joints on the south side of the corner have a mitered joint, with the angle pointing down. The top of the first piece fits flush with the top plate of the rigid wall, while the inside edge of the second piece fits flush with the bottom plate of the fold-down wall. A butt joint would work for the south side, but mitering the joint helps to shed water. The east and west sides of the corner use simple butt joints since a mitered joint would interfere with the motion of the fold-down wall section.

With the roof installed, the door rehung, the floor laid, and a few details like corner caps finished, it was time to paint the observatory. I chose light colors to enable me to see the immovable objects like posts that I don't wish to run into at night. A card table and a chair provide the basic furniture needed for my observing runs.

To commemorate the completion of construction, my wife Colleen gave me a redwood plaque engraved with the latitude and longitude of the observatory and with the year of construction to hang on the building. But I doubt that my observatory is finished. The building's design started as an answer to a list of inconveniences I suffered while observing. As my observing needs change, I will probably alter some things and add others.

After six years of planning and dreaming about having an observatory, I'm glad that I built it. No more batteries and inverters to carry so I have power for my telescope's drive. The walls protect me from moderate winds while I am trying to photograph the skies. And my feet are warmer than they were standing on the ground during the winter. Owl Observatory has fulfilled my dreams. ☐

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*Jim Krick uses his observatory to introduce children to the wonders of the night sky. Parts one and two of his series appear in the April and May issues.*

**Meade & Celestron**
LUMICON Carries a full line of telescopes & accessories. Fast Delivery, competitive prices.

# LUMICON FOR HIGH PERFORMANCE

## ASTROPHOTO OF THE MONTH

**Barred Spiral Galaxy NGC 1300** in Eridanus. Photo by David Healy using a Lumicon Giant EASY-GUIDER and hypersensitized 2415 film. 1 hour exposure, Celestron-14 at f/ı.

## TELE VUE™ EYEPIECES USE THE BEST!!

**ALL IN STOCK!**

| | |
|---|---|
| **Genesis 4'' f/5 4 element fluorite** | **$1560** |
| Pronto ı0mm f/6.4 refractor w/2'' diagonal | **$689** |
| Complete Eıuatorial Mount | **$795** |
| Motor Drive for above mount | **$198** |
| **7.4, 10.4, 13, 17, 21, 26mm Plossl** 50° | **$89** |
| **1.8x or 2.5x Tele Vue Barlow Lens** | **$89** |
| **2'' Giant Barlow - 2x** | **$219** |
| **32mm Plossl**, widest true field in 1¼'' | **$109** |
| **55mm 2'' Plossl**, widest possible field | **$219** |
| **15mm Wide-Field**, 1¼'' *eyepiece*, ı5° | **$135** |
| **19mm Wide-Field**, 1¼'' eyepiece, 65° | **$145** |
| **24mm Wide-Field**, "superb," 65° | **$169** |
| **32mm Wide-Field**, 2'' eyepiece, 65° | **$239** |
| **40mm Wide-Field**, "awesome," 65° | **$299** |
| **4.8mm Nagler**, 82° field | **$149** |
| **7mm Nagler**, 1¼'' eyepiece, 82° field | **$189** |
| **9mm Nagler**, 82° field, "the best" | **$219** |
| **11mm Nagler**, 82° field, 1¼'' or 2'' | **$235** |
| **13mm Nagler**, 82° field, 1¼'' or 2'' | **$249** |
| **12mm Nagler**, Type II, 82°, 1¼''/2'' | **$249** |
| **16mm Nagler**, Type II, 82°, 1¼''/2'' | **$289** |
| **20mm Nagler**, Type II, 82°, 2'' only | **$340** |
| **1¼'' Paracorr Visual Coma Corrector** | **$179** |
| **2'' Paracorr Visual Coma Corrector** | **$298** |
| **NEW! 22mm Panoptic 1¼''/2'', 68°** | **$249** |
| **NEW! 35mm Panoptic 2'', 68° field** | **$325** |

## ADJUSTABLE PIGGYBACK MOUNT

The LUMICON adjustable piggyback mount is ideal for telescopes of 6-16'' aperture. It permits **both** vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER™, large telephoto lenses and small telescopes up to about 5 lbs.
**LUMICON Adjust. Piggyback Mount $59.50**
Specify telescope size: 6'', 8'', 10'', 11'', 14'', 16''

## H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photograph with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter.

| **Specify Lens Size** | **H-Alpha** | **(MV)** |
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| 46, 48, 49mm | $49.00 | $39.00 |
| 52, 55, 58, 62mm | $59.00 | $49.00 |
| 67, 72, 77mm | $69.00 | $59.00 |
| 82mm | $79.00 | N/A |

Hypered 2415 film, 36 exp .. **$10.95, $3/$29**

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## NEW! ENHANCED ALUMINUM DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

**LUMICON 1.3'' & 2.1'' enhanced aluminum diagonal mirrors & 1¼'' star diagonal.**

*The new* LUMICON *diagonal mirrors* have a special enhanced aluminum coating with a protective overcoating for long life. Visible reflectivity is 94-96% compared to 86-89% for standard aluminum coated mirrors. The extra 5-10% transmission is like adding an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32'' **$29.95** 1.52'' **$34.50** 1.83'' **$39.50**
2.14'' **$49.50** 2.60'' **$65.00** 3.10'' **$89.50**

## ENHANCED ALUMINUM STAR DIAGONAL

90° star diagonals with 96% reflectivity enhanced aluminum mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

1¼'' (1.32'' mirror) **$99.50**
2'' (1.83'' mirror)(see photo above) .. **$159.00**

## LUMICON FILTERS — BEST IN THE WORLD!

***"The LUMICON OIII proved to be our favorite... It gave the greatest contrast gain."***
***ASTRONOMY February 1991***

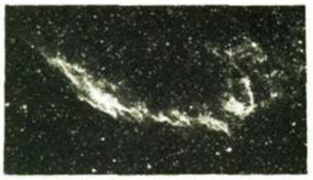
### AMAZING OIII FILTER™

**Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.**

The ultimate in filter performance! The Lumicon Oxygen-III Filter has a contrast twice as high as the high performance Lumicon UHC Filter™. Use the Oxygen-III Filter for observing the very faintest planetary and diffuse emission nebulae. Also gives incredible views of bright nebulae (like M-27, M-17, etc.) from urban locations. Bandpass is 11nm, transmission is 90% for both O-III lines at *496nm and 501nm.*

### SEE THE HORSEHEAD!

**Horsehead Nebula in Orion.** This faint nebula is seen best with a LUMICON H-Beta Filter. Photo by J. Marling using a Deep-Sky Filter.



### "I CAN SEE THE VEIL NEBULA!"

Rich Zepernick saw the Veil Nebula for the very first time with a **LUMICON UHC Filter**. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*
**Rich Zepernick, Cresskill, NJ**

### DEEP-SKY FILTER™

### BEST for Astrophotography!

*"Stunning is all I can say,"* says noted astrophotographer Jack Newton. *"Great for BOTH color and black and white photography."*

### BEST WIDE-BAND FILTER!

*"Based on our tests we'd recommend a LUMICON Deep-Sky and Oxygen-III as complimentary filters. The LUMICON Deep-Sky Filter clearly had the best contrast for* ***reflection*** *nebulae."*
***Astronomy, Feb. 1991***

**Premium***
**0.96'' LUMICON DEEP-SKY Filter** threads into most 0.96'' eyepieces **$59.50**
**1¼'' LUMICON DEEP-SKY Filter** threads into most 1¼'' eyepieces **$79.50**
**48mm LUMICON DEEP-SKY Filter** (1.7'' aperture), threads into most 2'' eyepieces. Also fits LUMICON EASY-GUIDERS **$119.50**
**2'' *LUMICON DEEP-SKY Filter*** *(1.5'' aperture), threads into most 2'' eyepieces.* Also has male & female camera T-threads for prime focus photography **$119.50**
**72mm LUMICON Giant DEEP-SKY Filter** (62, 67, 77mm adapter, $8) **$299.50**
**1¼'' LUMICON UHC Filter** threads into most 1¼'' eyepieces **$99.50**
**48mm LUMICON UHC Filter** (1.75'' aperture) fits most 2'' eyepieces **$199.50**
Set of both premium **DEEP-SKY** and **UHC Filters** (Save 11%) ... 1¼'' **$159.50**; 48mm **$279.50**
**LUMICON H-BETA Line Filter** (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. **1¼'' $99.50, 48mm $199.50**
**Oxygen-III Filter** for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm O-III lines **1¼'' $99.50, 48mm $199.50**
Telephoto lens adapter for 2'' or 48mm filter. Select 46, 49, 52, 55, 58mm **$6.95**
Universal adapter for 1¼'' filters. Adapts the 1¼'' filters to any 1¼'' eyepiece **$16.00**
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**Premium filters are currently the best in the world. All Lumicon filters include individually measured transmission data.*

# DEEP-SKY ASTROPHOTOGRAPHY

# SR-V 3200 NEW FILM

## FILM HYPERSENSITIZATION KITS†

**LUMICON HYPER-KITS™** yield 3-15x film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

U.S. Patent 4,473,636

## MAKE YOUR OWN HYPERED FILM

**MODEL 300 HYPER-KIT** sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds ..... **$325**

**MODEL 600 HYPER-KIT** (See photo) Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$395**

**MODEL 1200 HYPER-KIT** is for 4X5'' plates and film up to 5X7''. Has 2 gas cylinders and includes temperature controller ... **$595**

Temperature controller for any HYPER-KIT **$65**

Electric Vacuum Pump, Model R-10 **$325**

## GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars.
*Specify Camera and Telescope type.*
*U.S. Patent 4,448,500*

### NEWTONIAN EASY-GUIDER™

Full aperture. Installs in seconds. Specify 2'' or 1¼''.

NEWTONIAN EASY-GUIDER ...... **$169.50**
3X Relay Diagonal (see photo) ..... **$89.50**
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Guider for Hasselblad **$350,** Mamiya 645 **$199**
Pentax 6X7 **add $119;** Pentax 645 **add $139**

### CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Cynamax-8. Includes 50mm achromatic lens for f/5.8 operation—3X shorter exposures! **Superb rich field viewing, too!**

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For Celestron-11, C-14, and the 10'' Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER ........... **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20) ..... **add $99.95**
Adapter for Hasselblad **$229,** Mamiya 645**$129**
Pentax 6X7 **add $129;** Pentax 645 **add $149**

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1. Illuminated reticle eyepiece ...... **$99.50**
Lumicon 12mm eyepiece system has adjustable LED illumination, dual crosslines, battery pack.

2. Cable release for long exposures .. **$9.95**

3. **LUMICON Quartz Drive Corrector . $219**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 40Hz/80Hz variable output controls telescope drive. 60Hz Quartz reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Declination reverse switch for Newtonians.
**Declination motor (state telescope) .. $99**
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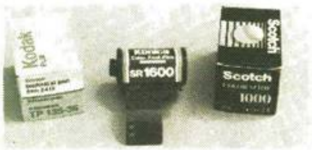

## HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.).***No C.O.D.s.***

| **Film Type, 35mm** | **Exposures** | **Price** |
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| 2415, Ultra-fine B&W, red sens. | 36 | **$10.95** |
| SR-G3200, fastest of all, color neg | 24 | **$13.95** |
| Kodak Ektar 1000 fast, fine grain | 24 | **$12.95** |
| Fuji HG400 fine grain color neg. | 12 | **$10.95** |
| 3M 1000, fastest slide film | 12 | **$12.95** |
| Fujichrome RD100, fine grain slide | 24 | **$12.95** |
| D-19 B&W Developer | 1 gal. | **$6.95** |

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See the Meade ad in this magazine for full specifications and product descriptions. ED = Extremely low dispersion glass which yields color-free virtually perfect images. PPEC = Permanent Periodic Error Correction "Smart Drive."

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| **Model 102 ED** 4" f/9 Apochromat and mount | **$1795** |
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| **Model 152 ED** 6" f/9 Apochromat and mount | **$3995** |
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### DRIVE SYSTEMS

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| **#1664 Electronic Drive** with PPEC and 2X, 32X slewing system, dual-axis controller | **$295** |
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| 8,000 object library of deep-sky targets | **add $99** |

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| **Model 152 ED/APO-OTA** 6" f/9 OTA only | **$2295** |
| **Model 178 ED/APO-OTA** 7" f/9 OTA only | **$2995** |

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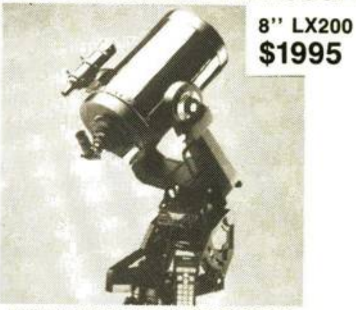
## NEW MEADE LX100 & LX200 SCHMIDT-CASSEGRAIN TELESCOPES


8" LX200
**$1995**

**NEW MEADE 8" LX200 TELESCOPES**

See the Meade ad in this magazine for full specifications and detailed product descriptions.

**LX100 Drive**, 2X, 32X speed control with PPEC (Permanent Periodic Error Correction "Smart Drive") and dual-axis hand controller.

**LX200 Drive**, Full electronic control with PPEC, 747 object computer memory and automatic computer controlled slewing to desired object.

*NOTE:* A wedge is **not** needed for visual observing with the LX200 Drive.

Specify f/6 or f/10 optics at the *same* price.

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| **10" LX200** Schmidt-Cassegrain with computer | **$2295** |
| **Super Wedge** for photography with LX200 | **$395** |

### OTHER SCHMIDT-CASSEGRAINS

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| **Meade 2080B** 8" f/10 with tripod, wedge, MCOG | **$1175** |
| **NEW! Model 2120B** 10" f/10 with wedge, tripod, MCOG | **$1595** |

### PHOTOGRAPHY ACCESSORIES

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| Cassegrain EASY-GUIDER for f/6.3 8" telescope | **$195** |
| LUMICON Giant EASY-GUIDER for 10" f/5-f/10 operation | **$395** |
| Giant EASY-GUIDER for f/6.3 10" telescope | **$295** |

## MEADE STARFINDERS

8" f/6
**$599***

**New 8" f/6 Meade Starfinder telescopes**

See the Meade ad in this magazine for full descriptions and technical specifications for 6" to 16" Starfinders. These are complete telescope systems with motor drive, mount, finderscope and 48X eyepiece.

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|---|---|
| **6" f/8 Starfinder 6**(add $50 shipping) | **$499** |
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| **10" f/4.5 Starfinder 10** (add $75 shipping) | **$699** |
| **16" f/4.5 Starfinder 16** (ship. freight COD) | **$1995** |

*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated shipping charge to the price. LUMICON showroom prices are $96 higher.

### ACCESSORIES

LUMICON carries the full line of Meade accessories. See the Meade ad in this magazine for detailed prices and descriptions.

| | |
|---|---|
| **Meade #43** Single axis drive corrector | **$99** |
| **LUMICON DX200** Dual-axis drive corrector | **$249** |
| **LUMICON DX2BP** Dual-axis drive corrector with built-in battery pack | **$299** |

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Higher Performance — Lower Price

## SKY VECTOR $399

NEW! With over 200 object memory including the 110 Messier objects.

## SKY VECTOR II™ $499

Only the LUMICON SKY VECTOR II has size, **true visual magnitude**, and complete **detailed visual description** for **all** 1500 objects in memory.

## NGC SKY VECTOR™ $699

**IMPROVED!—2002 Additions / Corrections**

NGC-Sky Vector
LUMICON

**Improved NGC SKY VECTOR with over 8,500 object memory including complete and corrected RNGC catalogue, and IC and planetary catalogues.**

**LUMICON NGC SKY VECTOR FEATURES:**
- All features of LUMICON SKY VECTOR II
- Complete *corrected* RNGC catalogue
- 740 nonexistent NGC objects identified
- 343 corrections to RNGC catalogue
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- 308 best planetary nebulae selected by Jack Marling in separate catalogue listing
- 268 best "Non NGC/IC" objects catalogued
- "IDENTIFY" program helps you identify an unknown object seen in eyepiece
- "GUIDE" program leads you to object
- Detailed visual or photographic descriptions
- RS-232 port for computer access
- Includes planets' ephemerides in computer

**Specify Telescope Type:** Meade 2045, 2080, 2120, C-8, C-11, Odyssey 8, 10, 13, 17½, Alt-Azimuth.

Ultima 8, 11 .. **add $25**, C-14 .. **add $75**

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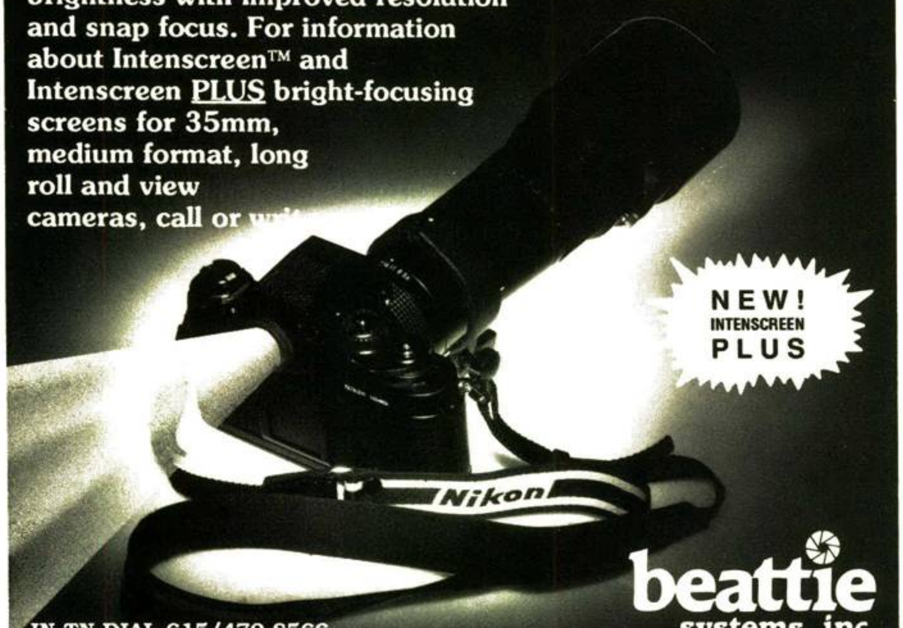

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***The Horsehead Nebula in Orion.*** *One of the best known examples of a dark nebula. Fifteen minute CCD image taken at the prime focus of a 25 inch, f/5 telescope. Courtesy Jack Newton, B.C. Canada.*

# LARGE-SCOPE DEEP-SKY OBSERVING

Robert Toebe of Fairfield, California, is not the typical deep-sky observer. Rather than wield a 6-inch refractor or a 10-inch reflector, Toebe uses a group of telescopes that includes a 30-inch reflector and the 20-inch refractor at Chabot Observatory. The small telescope he uses is an 18-inch Dobsonian. All of this equipment gives Toebe spectacular views of deep-sky objects, which he records on paper.

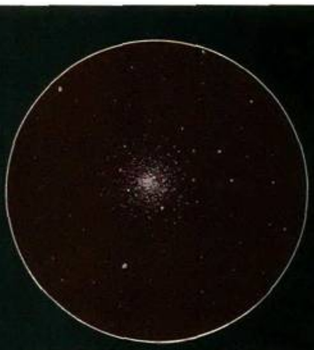
"Those of us who sketch deep-sky objects do it for many reasons," says Toebe. "The main reason is that galaxies and nebulae look much different in the telescope than they do in photos. I want to capture the way they really appear to human eyes."

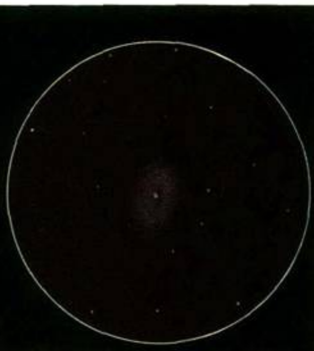
Toebe prefers to sketch the Messier objects because, as he says, "They offer the most detail." He is currently halfway finished sketching the Messier catalog. Favorites include galaxies like M82 in Ursa Major and M64 in Coma Berenices, and globular star clusters like M2 in Aquarius. Toebe also enjoys drawing unusual objects such as Abell clusters of galaxies, IC objects, and faint galaxies from the Uppsala catalog.

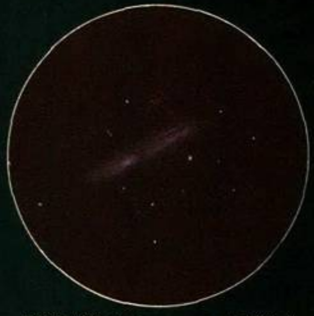
**Seeing Titan's Disk.** Gary T. Nowak of the Vermont Astronomical Society conducted an experiment last summer at the club's observatory in Williston. The objective was Saturn's moon Titan — not to spot it as a point of light but to resolve its disk, which measures 0.8" across. Nowak took on this challenge using the club's 10-inch f/20 Buchroeder Tri-Schiefspiegler, an instrument whose long focal length would provide large-scale images.

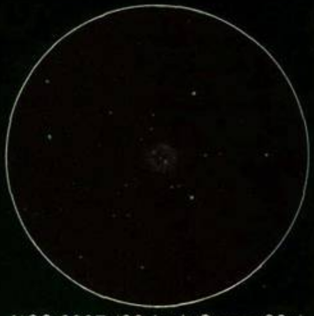
Nowak warms up by viewing Uranus and Neptune, whose blue-green disks are easily resolved. "My first view of Titan's disk came by accident," Nowak relates. "I was viewing Saturn's C ring with the 10-inch scope and suddenly the seeing snapped into crisp clarity. I quickly inserted a high-power eyepiece (317x) and tried to focus on Titan. The moon didn't focus down into a point, and the seeing degraded. I was foiled."

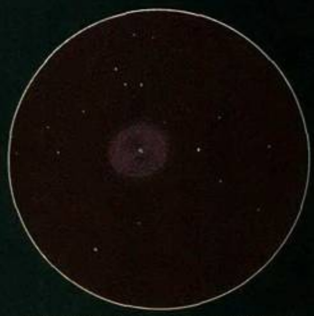
But Nowak would have another chance. On August 24, 1991, seeing and transparency were exceptionally good. "At 423x, Titan's disk was immediately visible, directly and without any question," says Nowak. "I recommend this as an unusual target for large-scope owners." — *David J. Eicher.*

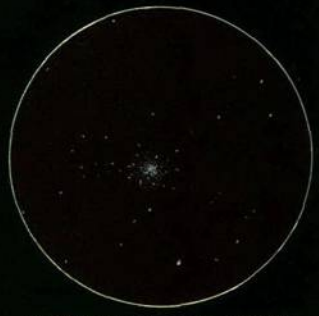

M2 (20-inch scpe at 328x)

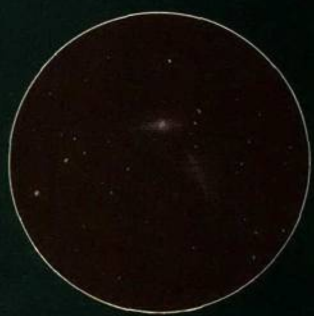

M64 (30-inch scope at 183x)

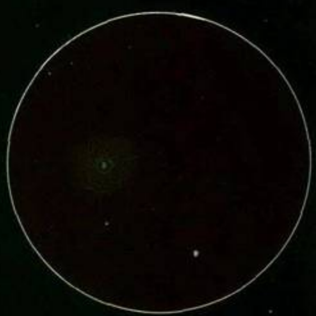

M82 (30-inch scope at 183x)


NGC 6337 (30-inch Scope 33x)


M97 (30-inch scope at 229x)


M80 (30-inch scope at 33X)


NGC 7332 and NGC 7339
(30-inch scope at 183x)


NGC 2392
(20-inch scope at 776x)

**LARGE-TELESCOPE VIEWS** of deep-sky objects result in bright, large-scale images that make for perfect sketches. Sketches by Robert Toebe.

# SOLAR SYSTEM WANDERERS

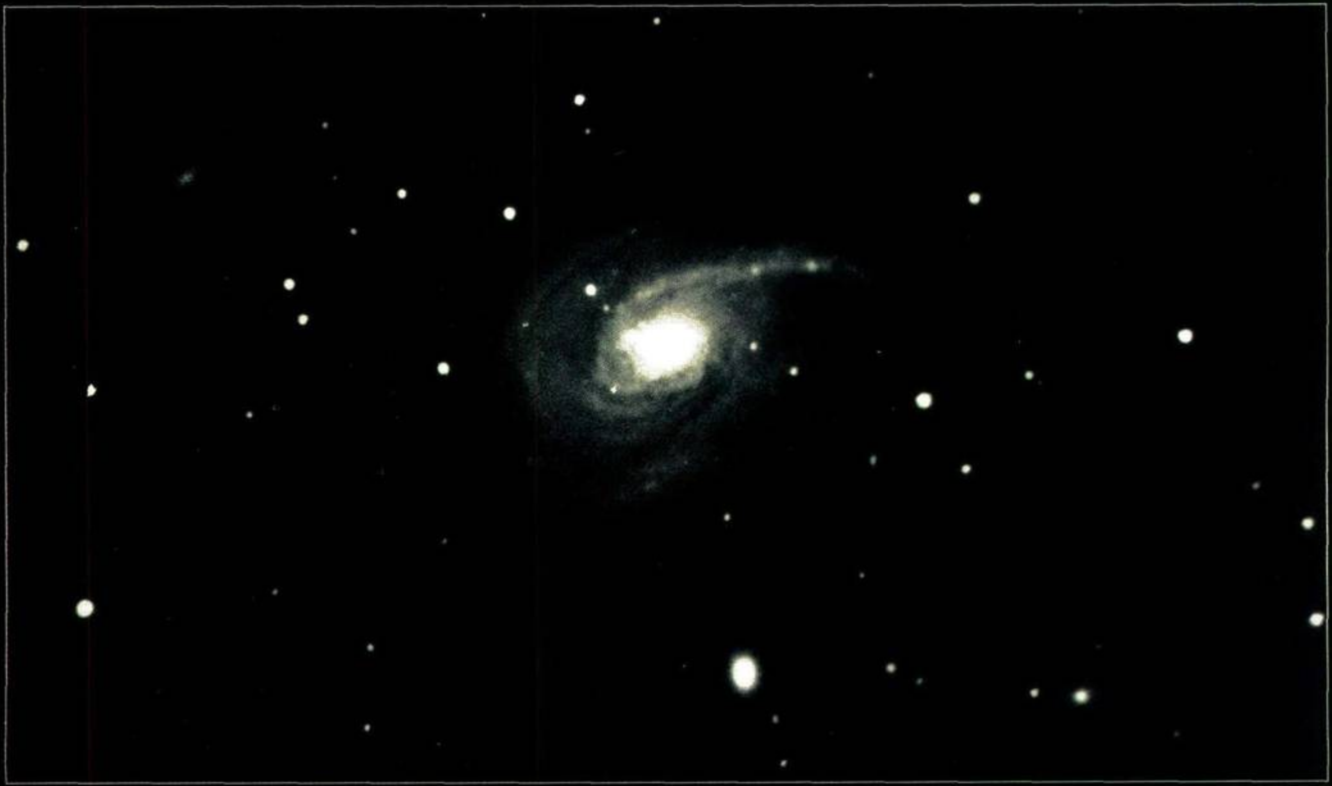
"FLASH!" The sky and ground lit up for an instant and then all was normal, save for a dusky gray trail left by the brilliant meteor. Such was the scene when Gordon Howell of Chesapeake, Virginia, photographed a Geminid fireball passing through Orion on December 13, 1991 (opposite page). Howell's photo wins this month's $100 "Best Astrophoto" award.

On September 14, 1991, Richard Andreassen of Auburn, Washington, captured a meteor as it flashed past the North America Nebula in Cygnus (left). Although meteors are visible every night, such close passages are rare.

Backyard astronomers photographed faint comets in 1991 as they never did before. Some of the objects they succeeded in imaging were Comet Zanotta-Brewington (1991$g_1$), photographed by Michael Stecker (below); Comet Faye (1991n), photographed by Chris Cook (bottom left); Comet Wirtanen (1991s), photographed by Jeffrey L. Jones (bottom center); and Comet Hartley 2 (1991t), photographed by Jeffrey L. Jones (bottom right).

*Comets and meteors weren't the only solar system wanderers recently caught on* film, however. On February 10, 1992, John Chumack of Dayton, Ohio, recorded asteroid 44 Nysa (arrow) as it slid past the Eskimo Nebula (NGC 2392) in Gemini (below left). At this time of closest approach, a mere 6′ separated the two objects.

A NEW YEAR'S SKY over East Islip, New York, saw Mercury, Venus, and the Moon together in the early morning of January 1, 1992. Mercury remained visible throughout January and underwent superior conjunction on February 12. Photo by Larry Landolfi.



THE STRANGE SPIRAL GALAXY NGC 772 reveals many tightly wound arms and a disk filled with dust. Photo by James Foster.

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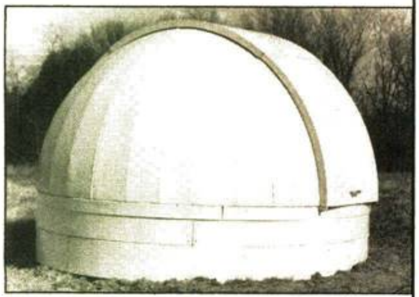

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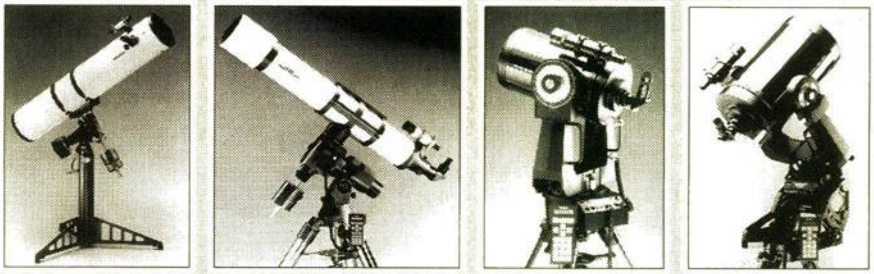

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*Lee Johnson, Coquitlam, B.C. Canada*

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# A NEW GUIDE TO AMATEUR ASTRONOMY

*The Backyard Astronomer's Guide*, by Terence Dickinson and Alan Dyer, (Camden House, 1991), ISBN 0-921820-11-9, 295 pages, sewn binding, hardcover, $39.95.

If you're thinking about purchasing a telescope or getting into astrophotography, here's your book. The authors do a wonderful job of touching on almost every facet of modern amateur astronomy — telescopes and binoculars, observing different types of astronomical objects, astrophotography — and they do it well. This highly informative book is also beautiful enough to go on the coffee table because of the numerous astrophotos taken by amateurs.

The authors divide the book into three main parts. "Equipment for Backyard Astronomy" covers binoculars, telescopes (from small refractors to huge Dobsonian lightbuckets), eyepieces, colored and light-pollution filters, and observing aids. Because the authors deal with specific brands, some information presented will go out of date as new telescopes and accessories appear on the market. But the emphasis is on sound, practical advice, such as how to decode telescope specifications, to assist you in purchasing a telescope.

For both beginners and advanced amateurs, "Nine Myths about Telescopes and Observing" will prove informative. The myths include some of my favorite topics — ones you are sure to hear mentioned at almost any star party. One myth is that high power should be reserved for planetary observing and low power used for deep-sky observing. But as the authors explain, many faint objects such as planetary nebulae and galaxies are small, so one must enlarge them enough to see their details.

But one of the myths mentioned, that telescope tubes should be white, has the wrong explanation. The authors say that black tubes are better because they radiate heat away and cool faster than white tubes. In fact, most paints radiate heat at about the same rate, regardless of color. [This is one of the corrections planned for the upcoming second printing of the book. — ed.]

"Observing the Celestial Panorama" does a good job of covering almost every facet of observing the sky. I say "sky" because the authors include not only the solar system and deep-sky objects but also various atmospheric phenomena and aurorae. The section also describes star hopping, setting circles, and many of the star atlases available to the amateur. I liked the short articles by noted experts in their particular field, such as observing comets by David Levy and sketching at the eyepiece by Gregg Thompson.

One chapter, "Observing Conditions: Your Site and Light Pollution," is must reading for all amateurs. Our learning about light pollution is vital to the health of amateur astronomy. This is the first amateur handbook I've seen that discusses light pollution in detail.

The third part of the book is devoted to astrophotography. Here the authors deal with selecting the right equipment and film for astrophotography and the various techniques used to photograph the Moon, planets, and deep-sky objects. One chapter deals with advanced astrophotography and the things that can go wrong when taking astrophotos.

*The Backyard Astronomer's Guide* finishes with a rich appendix that has sections on recommended books, amateur organizations, product sources, polar alignment, collimation, testing telescope optics, and a glossary of optical jargon by Peter Ceravolo that gives practical definitions of optics, coatings, and aberrations.

This excellent book gives lots of concrete, practical advice to amateurs who want to learn more about telescopes, observing, and astrophotography. — *Robert Bunge*

## SOLAR OBSERVING

*Observing the Sun*, by Peter O. Taylor, (Cambridge University Press, 1991), ISBN 0-521-40110-0, 159 pages, sewn binding, hardback, $29.95.

Written by the chairman of the solar division of the American Association of Variable Star Observers, this book describes equipment and techniques for observing sunspots and solar flares. Taylor starts by describing the sunspot cycle and the classification schemes for spot groups based upon their sizes and shapes. The main part of the book contains practical information for backyard observers on orienting telescope images, determining the latitude and longitude of sunspots, observing sunspot regions and solar flares, and computing sunspot numbers. For flare observers, the book includes a short description of electronic monitors. ☐

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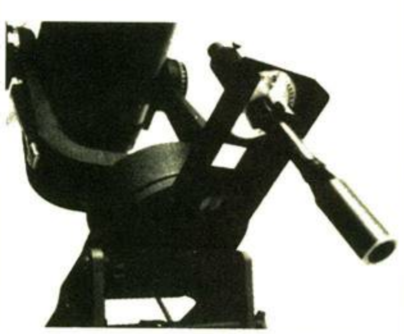

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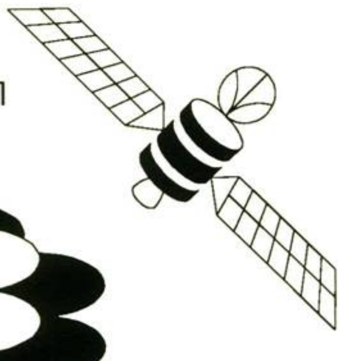

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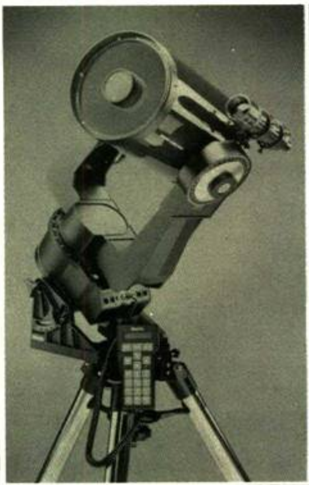

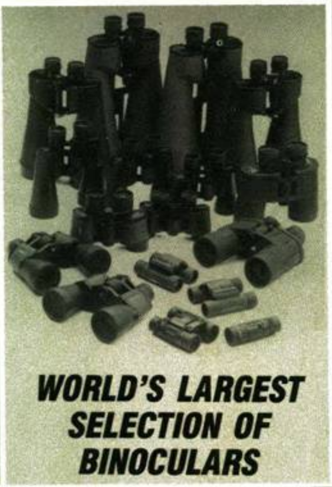

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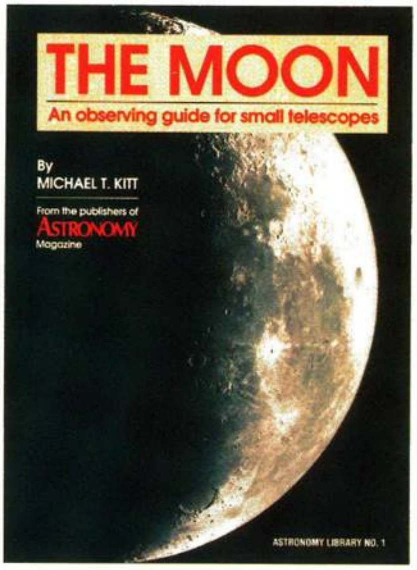

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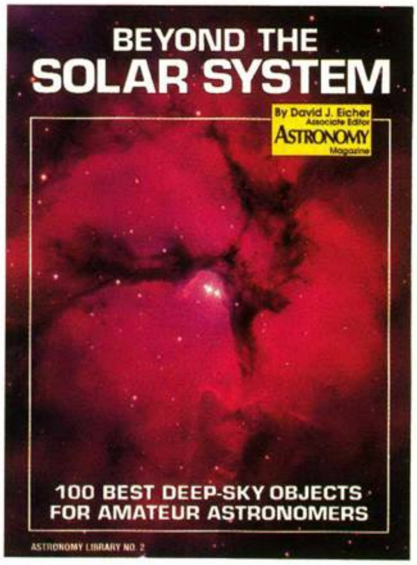

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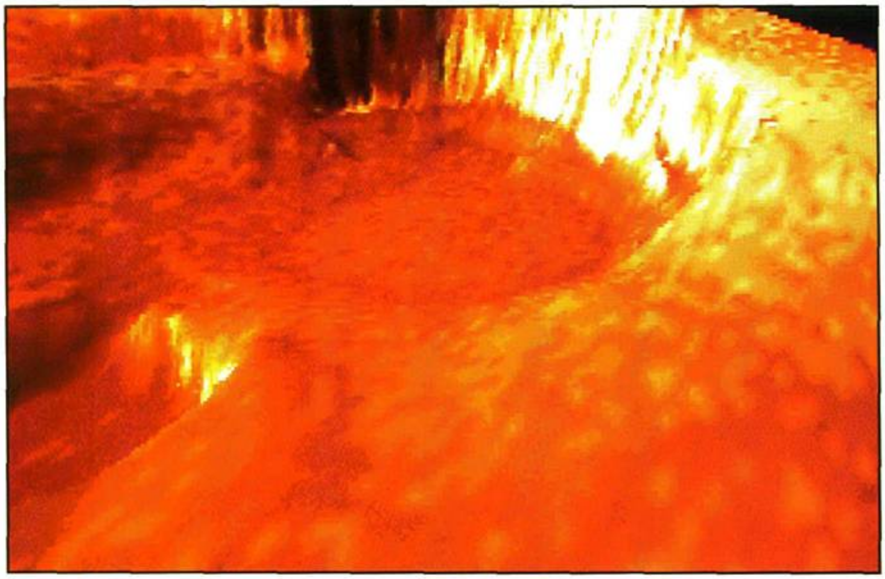
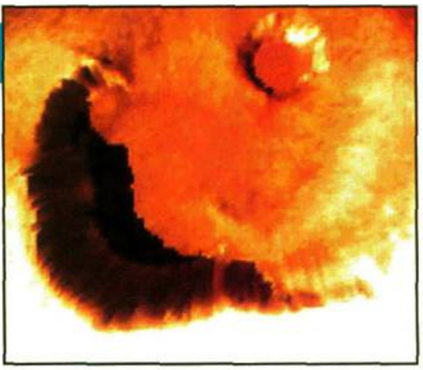
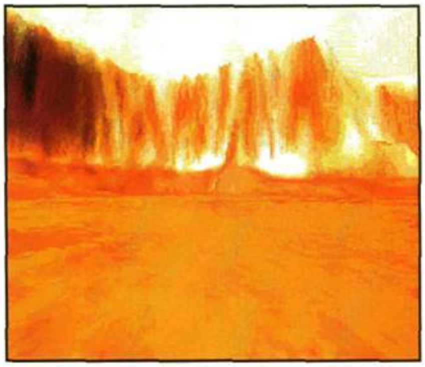






**VISTAPRO GENERATES 3-D LANDSCAPES** like these aerial (top) and surface (left and bottom) views of the caldera of Mars' Olympus Mons.

# VISUALIZING MARS' SURFACE

***VistaPro**, Virtual Reality Laboratories, Inc., 2341 Ganador Court, San Luis Obispo, CA 93401. Phone (805) 545-8515. $129.95 plus shipping and handling. Minimum requirements: IBM PC-compatible computer, 640 KB memory (540 KB free), VGA or higher (VESA drivers required for highest graphics level supported), hard disk with 3 MB free space, mouse. Includes both $5^1/_4$" and $3^1/_2$" diskettes. (An Amiga version is also available.)*

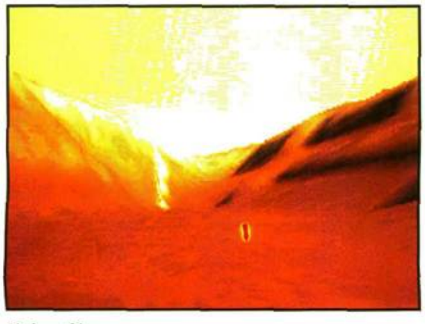
Imagine scaling the summit of the Martian volcano Olympus Mons and gazing at its volcanic caldera or hiking along Valles Marineris, getting lost in Noctis Labyrinthus (the Labyrinth of the Night). Journeys like these are no longer the wistful thinking of astronomers looking at Viking orbiter photos of Mars. VistaPro is a state-of-the-art visualization program that lets you explore the surface of Mars in ways you had only dreamed about.

VistaPro provides three-dimensional electronic landscapes. Using a simple computer-drawn map, you may choose an observation point and a viewing direction. Mimicking the operation of a camera, you can change the view by using a different "lens." To help decipher whether a feature is a hill or a valley, you can change the lighting angle. And to simulate flying over the landscape, VistaPro provides animation. You can also let your imagination really take over, placing rivers, lakes, and even trees on Mars' surface, just as Arthur C. Clarke is doing for his book project *The Snows of Mt. Olympus: A Garden on Mars.* Once your landscape appears just the way you want it, you can capture it as a PCX file for use in other programs or later redisplay.

The program is a little intimidating at first because of its power. It installs on the hard disk easily. But when I started the program, the control panel looked like something from a jet's cockpit. However, thanks to a well-written Quickstart guide, I was using the program in minutes.

Nineteen data files come with the program, including landscapes of Mount St. Helens before and after its eruption, sections of Yosemite Valley, and the caldera of Mars' Olympus Mons. Some of these landscapes are portions of over 25 larger data sets available separately from Virtual Reality. Valles Marineris is one such expansion disk (list price $80). It contains 160 data files covering the valley's length and several of the volcanoes to its north and west.

VistaPro is a unique program and I have yet to tire of its visualization capabilities. I continue to find new ways of displaying Martian landscapes that enable me see the terrain from a different perspective. However, a review wouldn't be complete without a list of program ills. My biggest complaint is that my boss won't let me *spend more time running this program.* It is addictive. So buyer beware. — *Dave Bruning*



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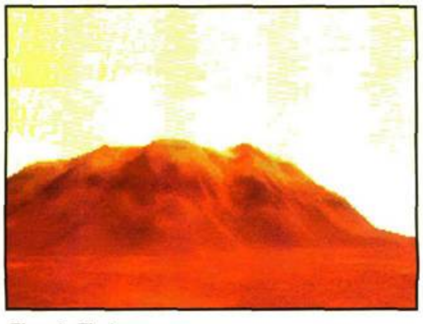

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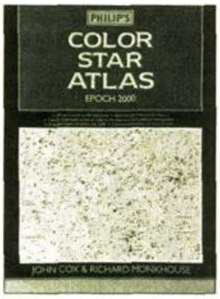

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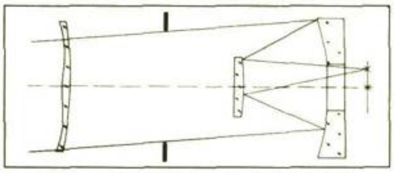

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| Wedge (8") | **110** |
| Superwedge (10") | **395** |
| Additional Object Library - adds 8000 CNGC objects to the LX200's built-in computer library | **99** |

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8 inch 2032mm F/10 Schmidt Cassegrain optics equatorial fork mount with motor drive, **wedge, tripod,** 6x30 finder, 1¼" diagonal,25mm eyepiece.

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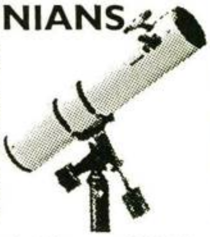

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**SPECIAL PRICE**

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Each of these fine instruments is matched to a Meade LXD 600 or 700 equatorial mount & metal field tripod. This brand new design features massive polar & dec. castings, eight ball bearings, and ultra-precise worm drives

**102ED** 4 Inch F/9 .................................. **1795**

Includes; Optical tube, 2.7" focuser, 2" diagonal, 8x50 finderscope 26mm New Super Plossl eyepiece, LXD600 equatorial mount, heavy duty metal tripod

**127ED** 5 Inch F/9 .............................. **CALL**

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Same as 102ED but with LXD 700 mount

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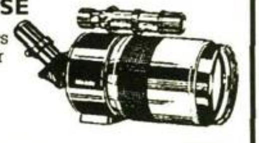

- 3½"1000mm F/11 optics
- 5x21 erect image finder
- 45° erecting diagonal
- 40x Meade eyepiece

**$307**

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| **97ER** Rubber Armored | **337** |
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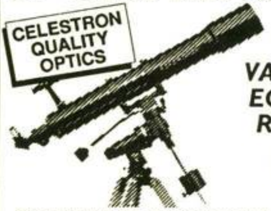

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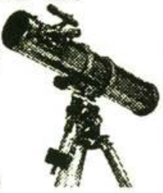
| C60E 2.4" Equatorial Refractor | 199.95 |
| Firstscope 80 3.1" Alt-Azimuth Refractor | 447.95 |
| SP-C80 3.1" Equatorial Refractor | 607.95 |
| SP-C102F 4" Fluorite Equatorial Refractor | 1698.95 |

## NEWTONIANS

### C4.5 NEWTONIAN



4½ inch 900mm F/7.9 Equatorial Newtonian with field tripod, 25mm 1¼" (36x) eyepiece, 5x24 finderscope **$427**

### SUPER POLARIS C6

6 inch 750mm F/5 wide-field Equatorial Newtonian with Super Polaris mount, field tripod, 18mm (42x) eyepiece, 6x30 finderscope **$719**

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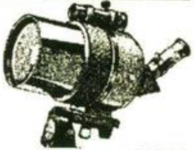
Use as a spotting scope telescope or camera lens
*Includes: 33x eyepiece, 8x20 erect finder, 45° erect prism, fitted carrying case.*



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| C90 Basic | 332.95 |
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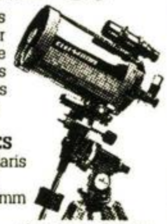
## SCHMIDT- CASSEGRAINS

### SUPER POLARIS C8



The Celestron Super Polaris C8 has long been Europe's most popular Schmidt-Cassegrain telescope. These fine instruments combine Celestron's famous 8 inch 2032mm F/10 optics with the versatile and easy to use Super Polaris equatorial mount.

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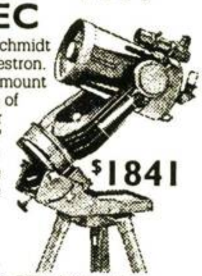
### ULTIMA 8 PEC



The state of the art 8 inch Schmidt Cassegrain telescope from Celestron. It features a rugged swing fork mount with carrying handles for ease of set up, a massive cast polar shaft with 4" ball bearings, 7½" Byers worm gear drive & PEC periodic error correction drive system for the ultimate in drive accuracy.

***COMPLETE FACTORY PACKAGE INCLUDES:***
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*All NGC computers are available for Bausch & Lomb 4000, 8000/8001, Celestron SP-C6/8/80/102, C5/8, Super C8/Plus, Classic 8, C11/14, Powerstars, Ultima 8/11/PEC Meade 2045/D, 2080/2120A/B/LX2//5/6, All Premiers, 2080/2120 GEM, All MTS, 826C, DS-10/DS-16.*

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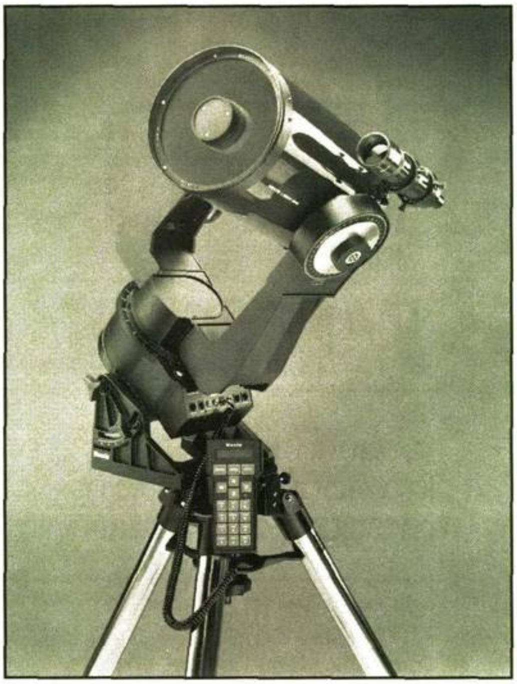

### 1 New Meade Schmidt-Cassegrains

Meade Instruments Corporation's newest models of Schmidt-Cassegrains are the 8-inch and 10-inch LX200 telescopes (8-inch model shown). The LX200 models feature massive fork mount assemblies and new computer-controlled drive systems. Included as standard equipment are a GO TO capability that permits the user to enter celestial coordinates of any object into the hand-held keypad display, press GO TO, and have the telescope automatically slew on both axes to the object. Alternately, the user may enter and locate any one of 747 objects in the keypad's software library (including all Messier objects, 278 of the best NGC objects, the 8 major planets, or one of 351 selected stars).

The telescope's drive system includes four drive speeds on both axes: 8° per second, 2° per second, 32x sidereal speed for centering, and 2x sidereal speed for photographic guiding. The telescope's computer drive also allows the instrument to be set up altazimuth — the computer automatically tracks objects using motions in both axes. Each LX200 includes an 8x50 viewfinder, diagonal prism, 26mm Super Plössl eyepiece, keypad hand controller, and field tripod as standard equipment. The wedge shown is optional.

*Meade Instruments Corporation, 1675 Toronto Way, Costa Mesa, CA 92626, (714) 556-2291. 8-inch LX200: $1,995; 10-inch LX200: $2,295.*

### 2 Astronomy Collectibles Catalog

Warren Blake Books has published a new free catalog of collectible astronomy books and prints. Offerings include 19th- and early 20th-century publications and some 18th-century and earlier works.

*Warren Blake Books, 308 Hadley Drive, Trumbull, CT 06611, (203) 459-0820.*

### 3 Obsession 20 — f/4 Version

To meet the demands of those looking for a compact and light large-aperture telescope, Obsession Telescopes has introduced an f/4 version of their Obsession 20 Dobsonian reflector. Features and design are the same as the original f/5 model with two exceptions: the truss poles are four feet long, making the eyepiece height at the zenith 72 inches, and the Galaxy Optics mirror is made from a precision annealed molded Pyrex blank that makes the f/4 telescope 25 pounds lighter than the longer focus f/5 model.

*Obsession Telescopes, 923 Stoney Road, Lake Mills, WI 53551, (414) 648-2328. $4,495. Shipping and crating extra. Send $2 for brochure and catalog.*

### 4 High-Eyepoint Binoculars

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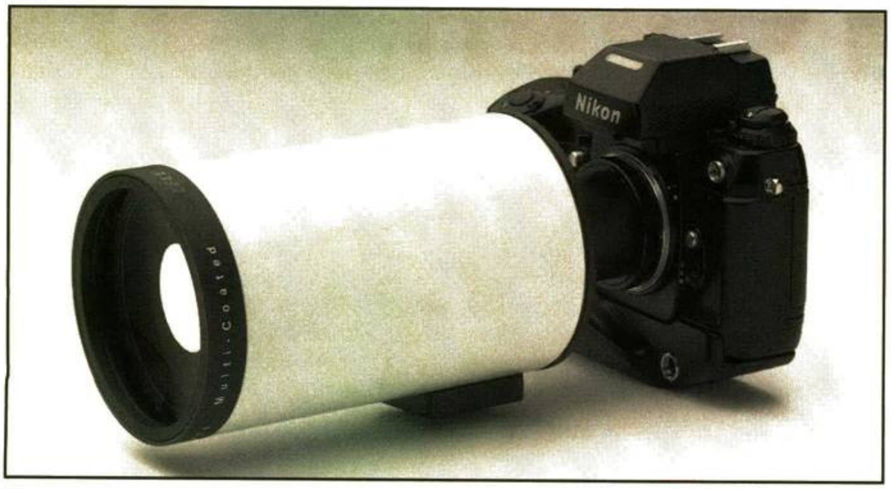
Unitron has introduced a new line of binoculars that offer long eye relief, a feature that makes it possible to see the entire field of view even when wearing eyeglasses. The series includes 7x50 and 10x50 models suitable for astronomy as well as a 5x32 roof-prism model for terrestrial applications. All models are weather resistant and come with cases and neck straps.

*Unitron, Inc., 170 Wilbur Place, P.O. Box 469, Bohemia, NY 11716, (516) 589-6666, FAX (516) 589-6975. 7x50: $150; 10x50: $155; 5x32: $210.*

### 5 Telrad Dew Shield

AstroSystems now offers a clip-on plastic dew shield for the Telrad™ reflex sight that is ideal for keeping dew and frost off the otherwise exposed sighting window. The dew shield is made of tinted acrylic and removes easily for safe transportation.

*AstroSystems, Inc., 1109 Kimbark Street, Longmont, CO 80501, (303) 678-5339. $10 plus $3 shipping. Telrad reflex sight not included. Call or write for free catalog.*



### 6 Improved 500mm Telephoto Lens

Celestron International has introduced an improved 500mm Maksutov-Cassegrain telephoto that operates at f/5.6 or, with an optional accessory, as a 350mm at f/4. The new lens features full-field illumination of a 35mm frame, even at f/4, built-in field flattener to reduce inherent field curvature, and broadband anti-reflection multicoatings. Close focus is 5 feet (3.5 feet with f/4 accessory). The lens comes with a soft case, tripod adapter, and built-in T-adapter.

*Celestron International, 2835 Columbia Street, Torrance, CA 90503, (800) 421-1526 or (310) 328-9560. 500mm lens: $558; f/4 accessory: $150.*

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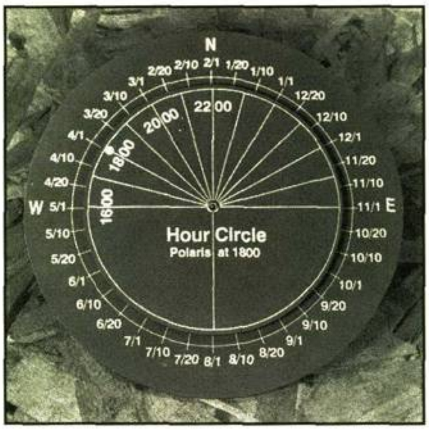
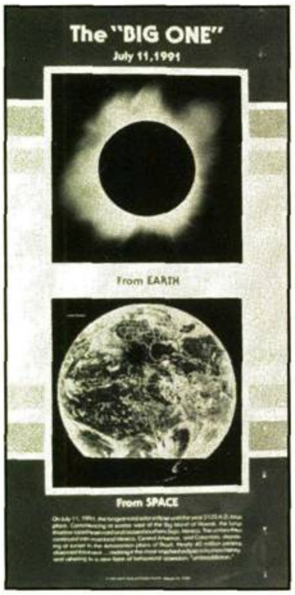


## 7 New Accessories from Astronomical Innovations

The NCP-7 (left) is a pair of 7-inch-diameter rotating disks that allow users to polar align any telescope with a Telrad™ reflex sight. By dialing in the current date and time, the NCP-7 gives you the correct angle to offset from Polaris to locate the true north celestial pole. The device is constructed of two 1/8-inch-thick plastic disks that glow in the dark.

The Sol-Mates (right) are a pair of Mylar solar filters for use with 80mm giant binoculars. They are designed to be used with Astronomical Innovations' DS-80 Dew Shields that slip over the objectives of most 80mm binoculars.

*Astronomical Innovations, P.O. Box 14853, Lenexa, KS 66285, (913) 894-5775. NCP-7: $11.95; Sol-Mates: $34.95; DS-80 Dew Shields: $18.95.*



## 8 Eclipse Poster

Twilight Tours is now offering a souvenir poster of last July's solar eclipse. The 17" by 34" poster shows an image of the total eclipse taken by Jeffrey Schroeder paired with an image taken by the GOES 7 weather satellite that shows the umbral shadow between Baja and the west coast of Mexico.

*Twilight Tours, Inc., 3316 W. Chandler Boulevard, Burbank, CA 91505, (818) 841-8245, FAX (818) 566-9677. $9.95 plus $3 mailing (rolled in cardboard shipping tube).*

## Waterproof 7x50 Binoculars 9

Designed for marine applications but suitable for astronomy, these new Zeiss binoculars are waterproof and salt-water resistant, and they feature individual eyepiece focusing and Zeiss T* multilayer coatings for maximum light transmission and contrast. They are also equipped with high-eyepoint eyepieces (suitable for eyeglass wearers), integrated front lens caps, a rain guard for the eyepieces, rubber armoring, and a red flotation neck strap.

*Carl Zeiss Optical, Inc., 1015 Commerce Street, Petersburg, VA 23803, (804) 861-0033. Suggested list: $1,760.*

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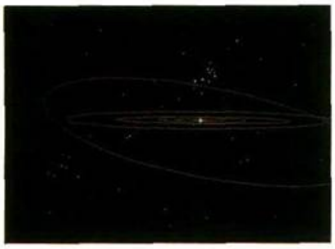
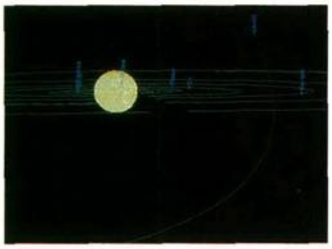
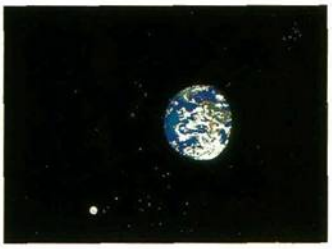


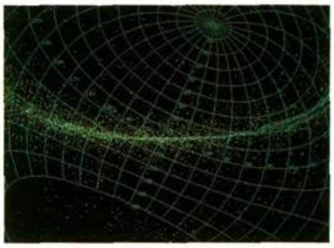
*The solar system from 36 light-hours distance.*



*Jupiter expelling comet Lexell from solar system in 1779.*

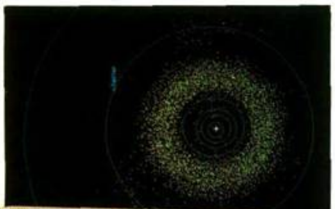


*Earth and Moon in Taurus, 16 Oct 2000.*

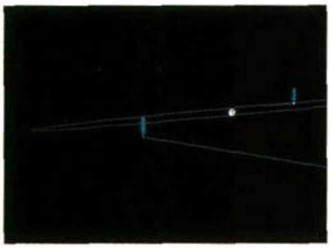


*Celestial Skymap with asteroids along the ecliptic.*

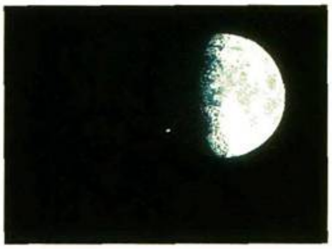
*Polar view of asteroid belt – Jupiter and the Trojan asteroids.*



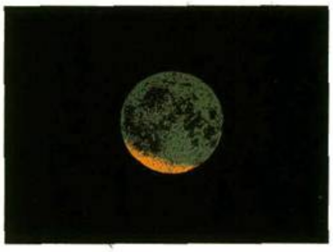
*Asteroid 1991BA passing close to Earth. 18 Jan., 17.5h, 1991.*



*Saturn slipping behind the moon. From Osaka Japan, 8 Oct. 1962.*



*Lunar eclipse of 9 Feb. 1990, near maximum.*



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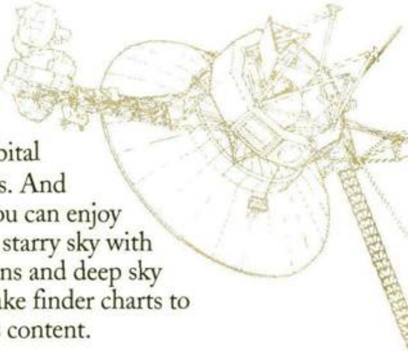

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## Meetings & Events

**May 20-22**
**International Amateur-Professional Photoelectric Photometry (IAPPP) Big Bear Symposium**. Contact: Bob Jones, P. O. Box 2203, Running Springs, CA 92382-2203.

**May 22-24**
**Riverside Telescope Makers Conference**, Camp Oakes, Big Bear, California. Contact: Riverside Telescope Maker's Conference, c/o Fox and Stephens, CPA, 9045 Haven Avenue #109, Rancho Cucamonga, CA. Phone: (714) 948-2205.

**May 22-24**
**Southern Star Astronomical Convention**. Sponsored by the Charlotte Amateur Astronomers Club. Contact: Harold Melvin, 418 School Circle, Harrisburg, NC 28075.

**May 29-31**
**Jersey Star Quest III**, United Methodist Camp, Browns Mills, New Jersey. Sponsored by the Amateur Astronomers Association of Princeton, Inc. Contact: Greg Mauro, P. O. Box 731, Princeton, NJ 08540. Phone: (609) 490-3560.

**May 30**
**Virginia Association of Astronomical Societies Annual Convention**, University of Virginia, Charlottesville, Virginia. Sponsored by the Charlottesville Astronomical Society. Contact: Richard Stanley, 110 Oakhurst Circle, Charlottesville, VA 22903. Phone: (804) 293-7976.

**May 30 - June 7**
**2nd Annual Grand Canyon Star Party**, Grand Canyon National Park, Arizona. Sponsored by the Tucson Amateur Astronomy Association. Contact: TAAA, 1122 East Greenlee Place, Tucson, AZ 85719.

**June 5-7**
**Arkansas Star Party**, Coleman Memorial Observatory, Hackett, Arkansas. Sponsored by the Arkansas-Oklahoma Astronomical Society. Contact: Arkansas-Oklahoma Astronomical Society, P. O. Box 31, Fort Smith, AR 72903. Phone: Joe Roam at (501) 474-4740.

**June 5-12**
**Beginning Astronomy Camp for Teens**, Tucson, Arizona. Sponsored by The University of Arizona's Alumni Association and Steward Observatory. Contact: Lisa Roubal or Kim Dow, Arizona Alumni Association, 1111 North Cherry, Tucson, AZ 85721. Phone: (800) 232-8278 (outside Arizona), or (602) 621-5233.

**June 12-13**
**22nd Annual Apollo Rendezvous and Telescope Fair**, Dayton, Ohio. Sponsored by the Miami Valley Astronomical Society and the Dayton Museum of Natural History. Contact: Ian Dumbauld, 5932 Culzean Drive, Apt. 706, Dayton, OH 45426. Phone: (513) 837-4600.

**June 19-21**
**Astronomical League Mid-States Regional Convention**, Avila College and Powell Observatory, Kansas City, Missouri. Sponsored by the Astronomical Society of Kansas City. Contact: Jackie Wade, Mid-States Chairman, 11305 King Street, Overland Park, KS 66210. Phone: (913) 469-0135.

**June 19-26**
**Advanced Astronomy Camp for Teens**, Tucson, Arizona. Contact: Lisa Roubal or Kim Dow (see June 5-12 entry).

**June 20**
**Ohio Association of Amateur Astronomers Conference**, Hiram College, Cleveland, Ohio. Contact: Cuyahoga Astronomical Association, P. O. Box 29089, Cleveland, OH 44129-0089. Phone: Bill Gerling at (216) 779-9779 (evenings).

**June 20**
**Prairie Star Party**, Bartlesville, Oklahoma. Sponsored by the Bartlesville Astronomical Society. Contact: Bartlesville Astronomical Society, Route 2, Box 940, Bartlesville, OK 74006. Phone: Ken Willcox at (918) 336-9900 (days), (918) 333-1966 (evenings).

**June 20-25**
**Universe '92**, University of Wisconsin, Madison, Wisconsin. Presented by the Astronomical Society of the Pacific and ASTRONOMY magazine. Contact: Wisconsin Meeting Information, Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112. Phone: (415) 337-1100.

**June 23-24**
**The Universe in the Classroom**, University of Wisconsin, Madison, Wisconsin. Contact: Astronomical Society of the Pacific, Teachers' Workshop Information, 390 Ashton Avenue, San Francisco, CA 94112.

**June 26-28**
**3rd Annual Mason-Dixon Star Party**, Spring Valley County Park, near York, Pennsylvania. Sponsored by the York County Parks Astronomical Society. Contact: Jeri Jones, 400 Mundis Race Road, York, PA 17402. Phone: (717) 771-9440.

**June 26-28**
**5th Annual Wisconsin Observers' Weekend**, Hartman Creek State Park, Waupaca, Wisconsin. Sponsored by the Northeast Wisconsin Stargazers. Contact: Don Wyman, 1815 Kienast Avenue, Oshkosh, WI 54901. Phone: (414) 233-3083 (evenings).

**July 1-5**
**General Assembly of the Royal Astronomical Society of Canada**, Calgary, Alberta. Contact: RASC-Calgary Centre, c/o Ms. Dennis Goodman, 28 Southland Crescent SW, Calgary, Alberta, Canada T2W 0K3. Phone: (403) 252-7095.

**July 3-5**
**Rocky Mountain Star Stare**, Badger Flats, Colorado. Sponsored by the Colorado Springs Astronomical Society. Contact: Colorado Springs Astronomical Society, P. O. Box 62022, Colorado Springs, CO 80962. Phone: Chris Wetherill at (719) 473-3621.

**July 13-18**
**Cosmocon '92 National Convention**, San Jose State University, San Jose, California. Sponsored by the Astronomical Association of Northern California. Contact: Don Stone, 4917 Mountain Boulevard, Oakland, CA 94619. Phone: (510) 376-3007.

**July 24-26**
**Summer Star Party,** Sleeping Giant Provincial Park, 40 miles northeast of Thunder Bay, Ontario. Contact: Rob Mace, P. O. Box 146, Vickers Heights, Ontario, Canada P0T 2Z0. Phone (807) 475-4091

**July 31 - August 2**
**Stellafane**, Springfield, Vermont. Contact: Stellafane, 60 Victoria Road, Sudbury, MA 01776. ☐

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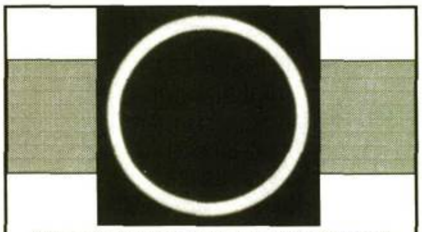

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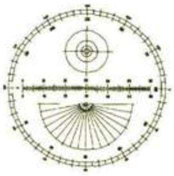

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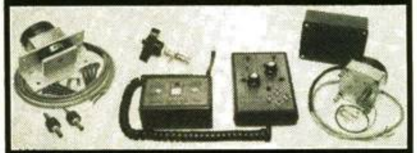

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## Readings & Resources

**Pulsar Planets** (page 36)

"The First Planet Beyond the Solar System" by Robert Burnham, ASTRONOMY, December 1991. Describes the first pulsar planet discovery.

"A Planetary System Around the Millisecond Pulsar PSR 1257+12" by A. Wolszczan and D. Frail, *Nature*, vol. 355, pages 145-147, January 9, 1992. A description of the discovery of the second, and now only, pulsar planet system.

"No Planet Orbiting PSR 1829-10" by A. G. Lyne and M. Bailes, *Nature*, vol. 355, page 213, January 16, 1992. Retraction of the first pulsar planet discovery.

**The Captive Asteroids** (page 40)

*Asteroids II* edited by R. Binzel, T. Gehrels, and M. S. Matthews (University of Arizona Press, 1989). A technical, comprehensive reference work with chapters accessible to lay persons.

*Introduction to Asteroids* by Clifford J. Cunningham (Willmann-Bell, Inc., 1988). A thorough survey of asteroid research that is rich in facts and details.

*Asteroids: Their Nature and Utilization* by Charles T. Kowal (Ellis Horwood Limited, 1988). A short, readable summary.

**Birth of Radio Astronomy** (page 46)

*Serendipitous Discoveries in Radio Astronomy* edited by K. Kellerman and B. Sheets, Workshop No. 7 (National Radio Astronomy Observatory, 1983). Several articles are by friends and family of Karl Jansky and one by Grote Reber.

*Big Ear* by John Kraus (Cygnus-Quasar Books, 1976). A personal account of the early days of radio astronomy by one of its pioneers.

**Draco Galaxies** (page 62)

*Beyond the Solar System: 100 Best Deep-Sky Objects for Amateur Astronomers* by David J. Eicher (AstroMedia, 1992). The sky's best galaxies, nebulae, and clusters, with photographs, data, star-hopping directions, and observational guides.

*Stars and Galaxies: ASTRONOMY's Guide to Exploring the Cosmos* edited by David J. Eicher (AstroMedia, 1992). Anthology describing bright and unusual regions of the sky for telescopic exploration; includes the Draco galaxies.

**Nightscapes** (page 72)

*The Backyard Astronomer's Guide* by Terence Dickinson and Alan Dyer (Camden House, 1991). Contains three extensive chapters on astrophotography.

*Astrophotography for the Amateur* by Michael Covington (Cambridge University Press, revised edition, 1990). A good guide to the basics of astrophotography.

## CREDITS

***Cover:*** Mark Paternostro; ***inset:*** Tony Hallas and Daphne Mount; ***p. 4:*** Larry Landolfi; ***p. 18, inset:*** Jack Newton; ***bottom left:*** Patrick Wiggins and Bruce Grim; ***bottom right:*** European Southern Observatory (ESO); ***p. 20, top:*** Don Womble et al. (*Astrophysical Journal*, March 20, 1992); ***bottom:*** Andrew Taylor and Brad Wallace (University of Calgary) and Miller Goss (NRAO); ***p. 22, top:*** Jan Hollis et al. (*Astrophysical Journal*, July 1992); ***bottom:*** ESO; ***p. 24:*** ESO; ***p. 26, top:*** Schott Glaswerke; ***bottom:*** Los Alamos National Laboratory; ***pp. 28-35:*** illustrations by Phil Kirchmeier; ***pp. 36-38:*** illustrations by Robert Wegner; ***p. 40:*** illustration by William Hartmann; ***pp. 42-43:*** illustrations by Lee Vande Visse; ***p. 44:*** NASA/JPL; ***p. 46:*** NRAO; ***p. 47:*** Bell Telephone Labs and NRAO; ***p. 48, top:*** Dave Bruning; ***bottom:*** NRAO; ***p. 49:*** Alan Dyer; ***p. 52:*** Carter Roberts; ***p. 53:*** Ivan Dryer; ***p. 55:*** Mark Payne-Gill; ***p. 62, top:*** Bill Iburg, 14-in. SCT at f/5.5, Ektachrome 400, 40-min. exp. with cold camera; ***bottom:*** Jack Newton, 16-in. f/5 reflector, 14-min. exp.; ***p. 63:*** Bill Iburg, 14-in. SCT at f/7, hypersensitized Konica SR 400, 40-min. exp.; ***p. 64:*** Kim Zussman, 14.5-in. f/8 Cassegrain, hypersensitized Tech Pan, 120-min. exp.; ***p. 65:*** Martin C. Germano, 8-in. SCT at f/5, 103a-F, 35-min. exp.; ***p. 66:*** Robert Nelson; ***p. 67, top:*** illustration by Robert Wegner; ***bottom:*** Stephen Walther; ***pp. 68-69:*** illustration by Steve Davis; ***p. 70, top:*** Stephen Walther; ***p. 70, bottom:*** illustration by Robert Wegner; ***p. 71, top:*** Ken Fye; ***bottom:*** illustration by Robert Wegner; ***pp. 72-73:*** Chris Dunmill, 50mm lens at f/2.8, Fujichrome 400, 10-min. exp.; ***p. 74, middle:*** Jerry Schad, 24mm lens, ISO 1600, 45-sec. exp.; ***inset:*** Allan Morton, 35mm lens at f/2, ISO 400, 20-sec. exp.; ***p. 75, middle:*** Brian Kimball, 4x5 view camera with 135mm lens at f/8, Fujichrome 50, 7.5-hour exp.; ***inset:*** Jerry Schad, 35mm lens at f/2, Ektachrome P800/1600 film processed at ISO 1600, 15-min. exp.; ***p. 76:*** William Sterne; ***pp. 76-77:*** Brian Kimball, 50mm lens at f/2.8, Kodachrome 64, $^{1}/_{4}$-sec. exp., June 1991; ***p. 77:*** Jim Eager, Fujichrome 400, 1-min. exp.; ***p. 80:*** illustration by Lee Vande Visse; ***p. 81:*** Jim Krick; ***p. 82:*** illustration by Lee Vande Visse; ***pp. 83-85:*** Jim Krick; ***p. 89:*** Robert Toebe, 20-in. and 30-in. reflectors at 183x-776x; ***p. 90:*** Glendon Howell, 50mm f/1.8 lens, Fujicolor Super HR 1600, 2-min. exp. on December 13, 1991; ***p. 91, top left:*** Richard Andreassen, 135mm f/3.8 lens, Agfachrome 1000, 20-min. exp. on September 14, 1991; ***p. 91, left center:*** John Chumack, 16-in. f/4.5 reflector, Ektar 1000, 6-min. exp. on February 10, 1992; ***p. 91, bottom left:*** Chris Cook, 8-in. f/10 SCT, hypersensitized Tech Pan, 35-min. exp. on October 5, 1991; ***p. 91, top right:*** Michael Stecker, 11-in. SCT at f/6, hypersensitized Fujichrome 100, 40-min. exp. on January 28, 1992; ***p. 91, bottom center:*** Jeffrey L. Jones, 8-in. f/10 SCT, hypersensitized Tech Pan, 15-min. exp. on November 4, 1991; ***p. 91, bottom right:*** Jeffrey L. Jones, 8-in. f/10 SCT, hypersensitized Tech Pan, 15-min. exp. on November 4, 1991; ***p. 92 top:*** Larry Landolfi, 50mm f/2.8 lens, Velvia, 20-sec. exp. on January 1, 1992; ***p. 92, bottom:*** James Foster, 14-in. SCT at f/11.5, hypersensitized Tech Pan, 240-min. exp.; ***p. 99:*** Darla Gawelski.

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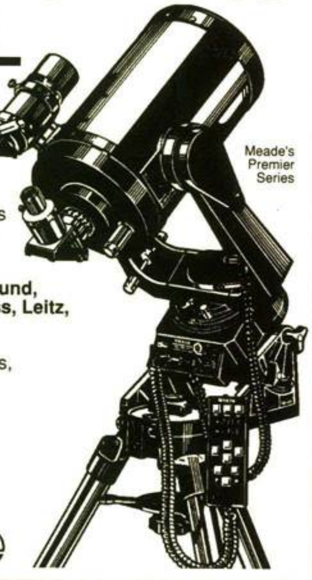

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## PRECISION SOLAR FILTERS

***Thousand Oaks Optical*** solar filters are recognized around the world for their quality, consistent density and even coating across the entire aperture. We specialize in solar filters only and are the largest solar filter manufacturer in the world. Filters are available to fit all brands of telescopes and binoculars. **Thousands of our filters are in use around the world. The preferred choice of telescope dealers and exclusively used by NASA aboard the Space Shuttle.**

**TYPE 1** - Made from high quality hand select glass, machine polished and **TRIPLE COATED** with a Nickel-Chromium alloy (same as Inconel). Mounted in a machined aluminum cell ready to attach to telescope. Solar image is yellow-orange. No secondary filtering is necessary.

**TYPE 2** - Same as type 1, except stainless steel is combined in the coating to provide an even more durable surface that highly resists wear due to excessive handling and ultraviolet radiation. Solar image is also yellow-orange.

**TYPE 3** - Coated to a neutral density of 4 for serious astrophotographers who desire the shortest possible shutter speeds with slow films. Solar image and optical quality same as type 1 and 2. Type 3 filters are for photographic use only.

Type 1 & 2 are for unlimited visual use and general photographic use. Instructions included with all filters, including tips on solar photography.

Our filters are many times more durable than common aluminized Mylar. Aluminized plastic cannot hold up to long term ultraviolet radiation and environmental contaminants as well as Nickel-chrome and stainless steel coated glass. Wrinkled Mylar can cause visual and photographic difficulties, can be easily damaged in handling or if placed on an uneven surface, and is difficult to clean. Also, a light blue solar image does not yield as much detail and contrast.

**GLASS (Full Aperture) Type 1**

| Aperture | mounted: | Aperture | unmounted: |
|---|---|---|---|
| 2.4" | $ 49.00 | 2.4" | $ 39.00 |
| 3.1" | 52.00 | 3.1" | 42.00 |
| 3.5" to 4" | 59.00 | 3.5" to 4" | 49.00 |
| 4¼" to 5" | 74.00 | 4¼" to 5" | 64.00 |
| 6" | 79.00 | 6" | 69.00 |
| 8" | 95.00 | 8" | 85.00 |
| 10" | 109.00 | 10" | 99.00 |
| 11" | 119.00 | 11" | 109.00 |
| 12.5" to 13.1" | 149.00 | 12.5" to 13.1" | 129.00 |
| 14" | 169.00 | 14" | 149.00 |
| 40mm to 80mm Binoculars - Mounted | | | $ 92.00 pr. |

**GLASS (Full Aperture) Type 2**

| Aperture | mounted: | Aperture | unmounted: |
|---|---|---|---|
| 2.4" | $ 62.00 | 2.4" | $ 52.00 |
| 3.1" | 65.00 | 3.1" | 55.00 |
| 3.5" to 4" | 76.00 | 3.5" to 4" | 66.00 |
| 4¼" to 5" | 96.00 | 4¼" to 5" | 86.00 |
| 6" | 105.00 | 6" | 95.00 |
| 8" | 125.00 | 8" | 109.00 |
| 10" | 139.00 | 10" | 119.00 |
| 11" | 149.00 | 11" | 139.00 |
| 12.5" to 13.1" | 179.00 | 12.5" to 13.1" | 159.00 |
| 14" | 199.00 | 14" | 179.00 |
| 40mm to 80mm Binoculars - Mounted | | | $115.00 pr. |

**GLASS (Full Aperture) Type 3**

| Aperture | mounted: | Aperture | unmounted: |
|---|---|---|---|
| 2.4" | $ 79.00 | 2.4" | $ 65.00 |
| 3.1" | 82.00 | 3.1" | 69.00 |
| 3.5" to 4" | 99.00 | 3.5" to 4" | 79.00 |
| 4¼" to 5" | 125.00 | 4¼" to 5" | 110.00 |
| 6" | 135.00 | 6" | 115.00 |
| 8" | 159.00 | 8" | 139.00 |
| 10" | 172.00 | 10" | 152.00 |
| 11" | 199.00 | 11" | 179.00 |
| 12.5" to 13.1" | 229.00 | 12.5" to 13.1" | 209.00 |
| 14" | 259.00 | 14" | 239.00 |

**THREADED CAMERA FILTERS**

All standard sizes available from 46mm to 82mm in Type 2 or Type 3. Please call or write for additional information.

**ORDERING INFORMATION:** Solar filters are shipped free in continental U.S. when payment is included with order. Shipping extra on credit card orders ($3 - $6 depending on aperture). Payment may be made by personal check, bank check or money order. We also accept **Visa, Mastercard** and **American Express. PLEASE SPECIFY TELESCOPE BRAND AND/OR OUTSIDE DIAMETER MEASUREMENT OF TELESCOPE TUBE.** The cost of the filter is based on the telescope aperture. The mounting cell fits over and around the end of the telescope tube (friction fit). The coating faces the inside. Unmounted filters are the glass only.

Free brochure available. Foreign inquiries: Please include $1 for return airmail postage of brochure. Proforma invoices available upon request.

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**SOLAR ECLIPSE VIEWERS**

**Mylar**

Aluminized on both sides. Mounted in rigid frame. Mylar window: 1 5/8" x 3 1/8". Each filter supplied in individual envelope. Light transmission is blue.

**3" x 5" Overall size ........................ $1.00 ea.**

**Plastic**

Same as Mylar except this filter yields a sharper image with orange transmission.

**2 5/8" x 4 5/8" Overall size ................. $2.00 ea.**

Minimum order of 10 eclipse filters in any combination. Please add appropriate shipping/handling. 10 units: $3.00. Plus $1.00 for each additional 10 units. Minimum credit card order of $25.00. Quantity discounts available starting at 100.

Mylar and plastic viewers are coated to a neutral density of 5. Transmission in visual light is approximately 1/1,000th of one percent. There is no significant transmission in ultraviolet or infrared. Designed for naked eye visual use.

THOUSAND OAKS OPTICAL
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**Farmington, Michigan 48332-8098**
**Phone: (313) 353-6825** Fax: (313) 350-3111

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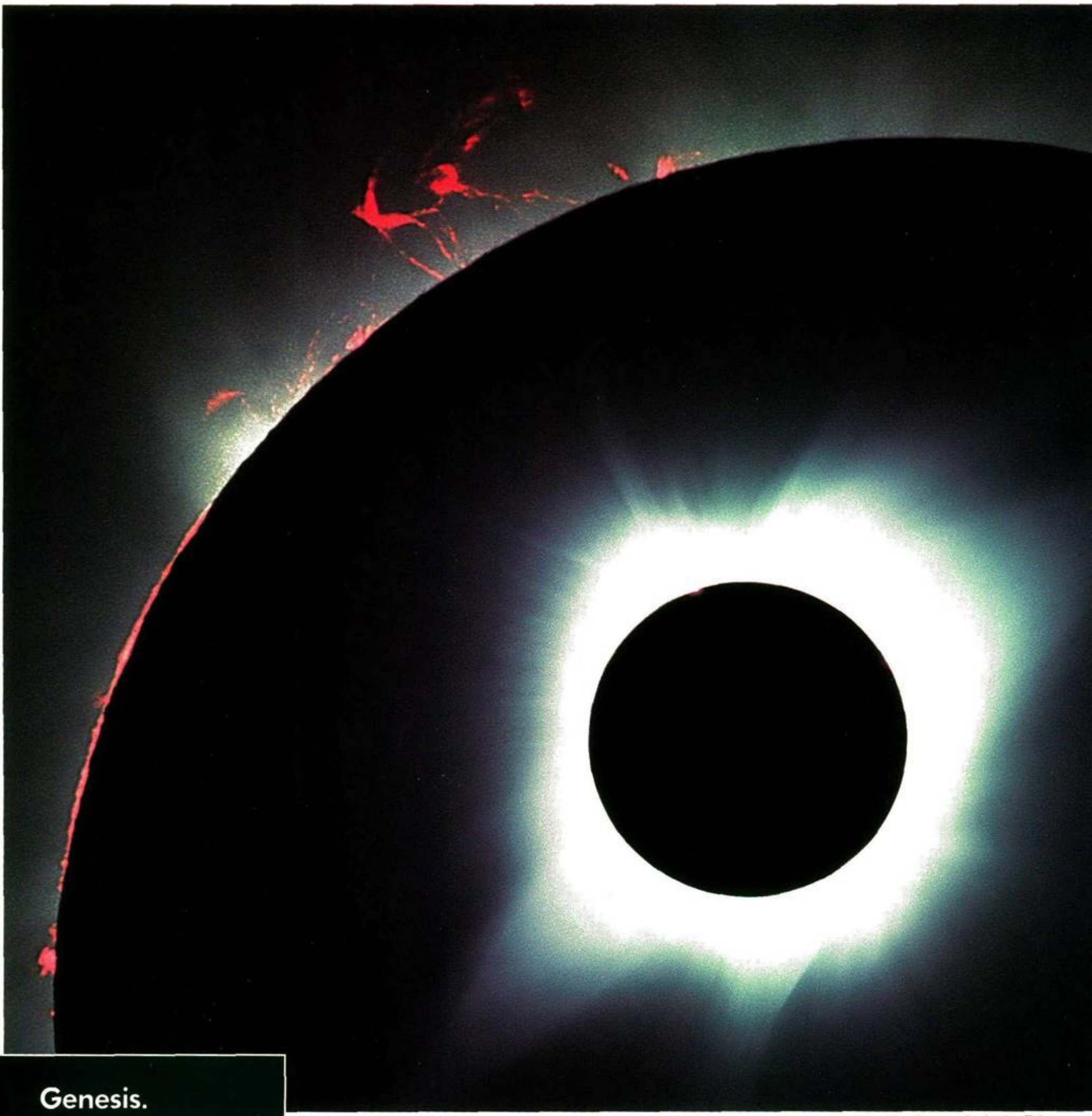
(Background photo taken through the NGT-18 by Dave Young)

GENESIS



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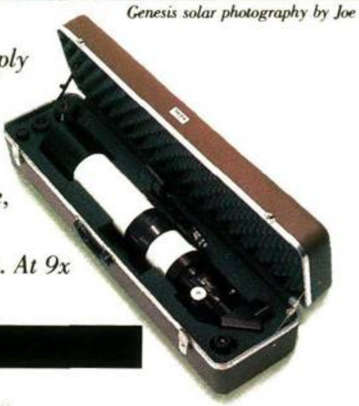

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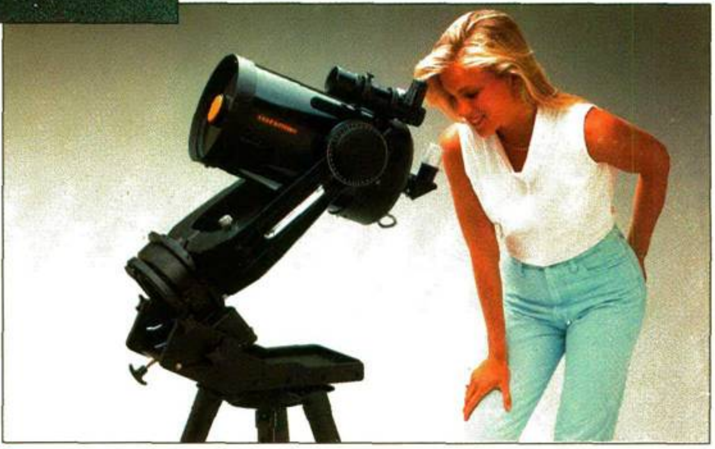
**Ultima 8 Photo - M8 - 30 min.@ f/6.3 - Std. ASA 3200 film - 35mm full frame under dark skies**



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